5.12 AMS ELECTRONICS

The AMS avionics primary functions are front end data collection for the scientific instruments, data and command communication interface between the various portions of the payload, as well as between the payload and the STS and ISS; and power distribution throughout the payload. The details provided in this section are broken down into the following subsections:

- AMS Electronics Systems Architecture Description
- Power Interfaces
- Power Distribution System (PDS)
- Cryomagnet Avionics Box (CAB)
- Cryocooler Electronics Box (CCEB)
- High Voltage Sources
- Grounding/Bonding Scheme for the AMS Experiment
- AMS-02 Integration Cabling De-Rating

5.12.1 AMS Electronics Systems Architecture Description

AMS-02 contains numerous electronics boxes, some termed "Crates," that supply the necessary readout/monitor/control electronics and power distribution for each detector (Figures 5.12.1-1 and 5.12.1-2). The box nomenclature is generically x-Crate or xPD, where "x" is a letter designating the detector function, and "Crate" refers to the readout/monitor/control electronics box and "PD" refers to the Power Distribution box for that specific detector. Similarly xHV bricks provide high voltage for some detectors. Values of "x" are designated as follows:

- E ECAL
- J Main Data Computers (MDC) and Command & Data Handling interfaces
- JT Trigger and central data acquisition
- M Monitoring
- R RICH
- S Time of Flight (TOF) Counters and Anti-Coincidence Counters (ACC)
- T Tracker

- TT Tracker Thermal
- U Transition Radiation Detector (TRD)
- UG TRD Gas

Additionally, electronics are mounted in the Power Distribution System (PDS), the Cryomagnetic Avionics Box (CAB), the Cryocooler Electronics Box (CCEB), and the Uninterruptible Power Supply (UPS). A small amount of electronics are also mounted directly on the detectors themselves, and are described in the detector section.

The interface boxes PDS and J-Crate provide the isolation and protection functions necessary to protect the STS and ISS vehicles from damage. Therefore, detailed internal box design for each of the detector crates will not be supplied; however, those which contain High Voltage sources will be identified, and the controls explained in Section 5.12.7.

One of the most critical safety functions to be performed for ISS protection is the isolation and protection of the Power Distribution System from the ISS, as described in Section 5.12.3. In most cases the PDS provides the isolation and circuit protection required to prevent feedback to the ISS; however, the Cryomagnet Avionics Box (CAB); the Cryocooler Electronics Box (CCEB); and some Heater Circuits receive 120Vdc pass-through power from the PDS. Explanation of their isolation and protection schemes is also included.

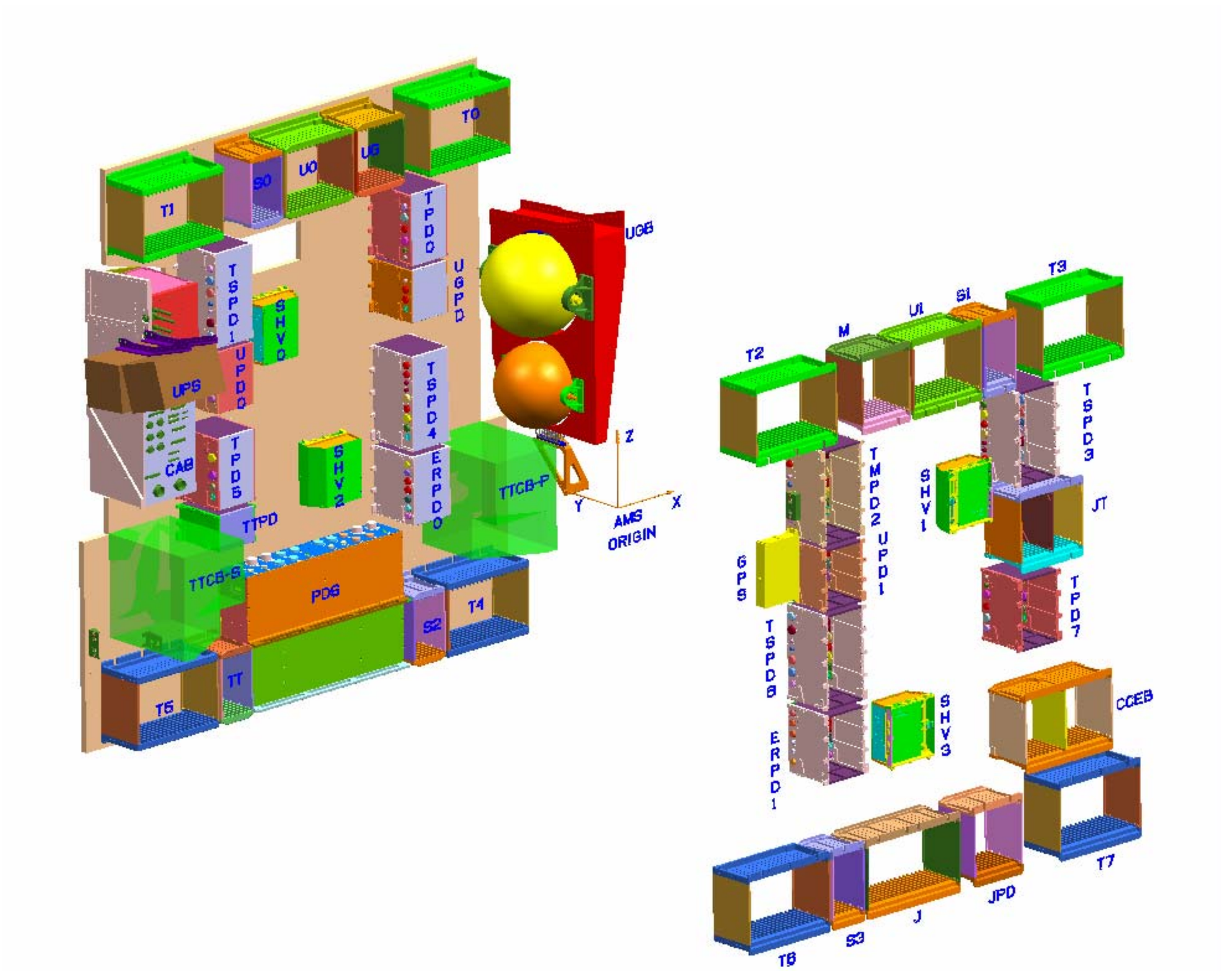


Figure 5.12.1-1 Electronics Crate Locations

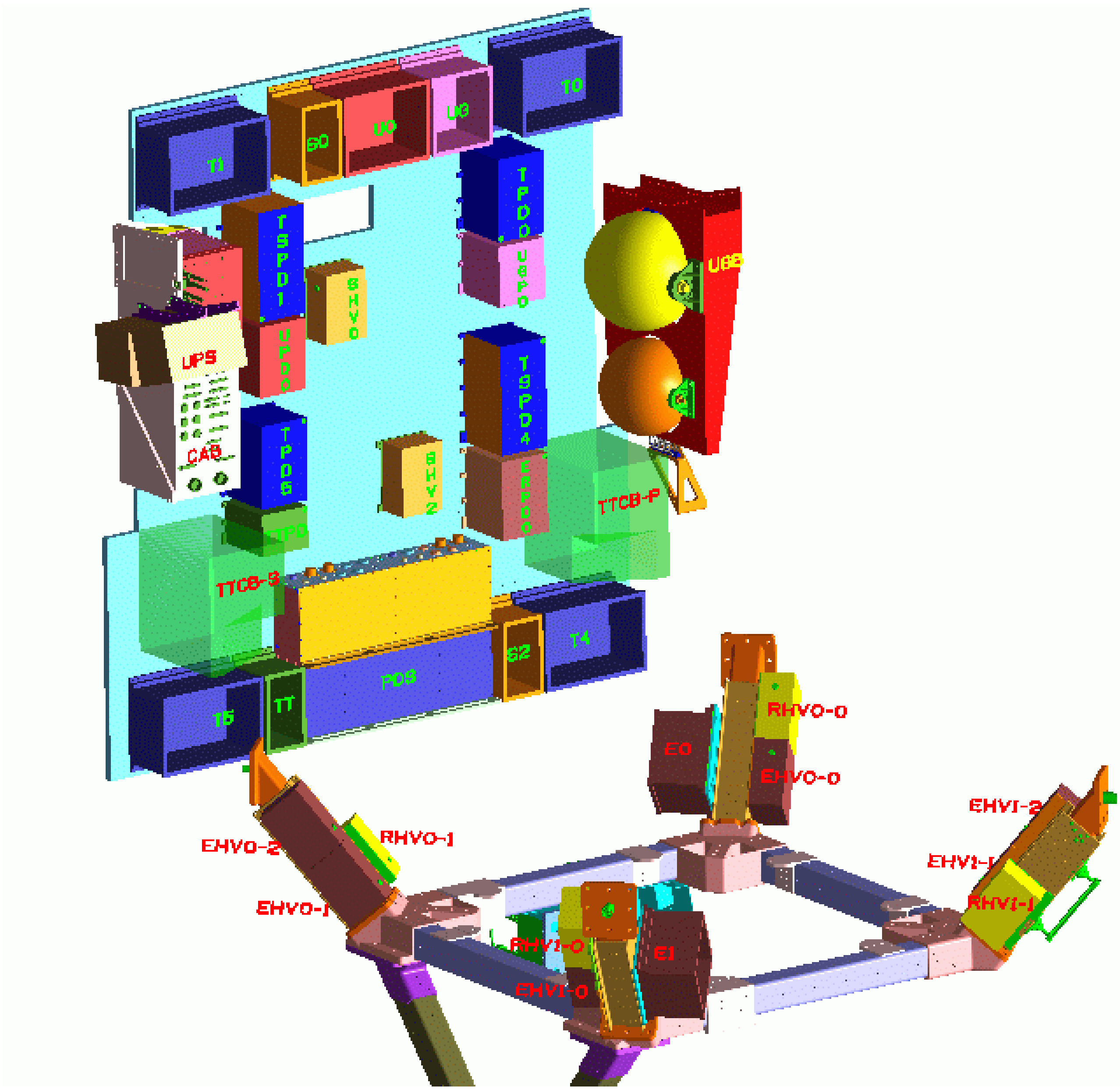


Figure 5.12.1-2 Electronics Crate Locations

5.12.2 Power Interfaces

The AMS-02 Power Distribution System (PDS) serves as the primary front-end for the power distribution to the subsystems and experiment detector electronics. It performs power conversion and distribution functions described in Section 5.12.3. The power isolation within the PDS, also described in Section 5.12.3, is designed to meet the 1 Mega Ohm Isolation requirement defined in SSP-57003.

Wire sizing has been selected in compliance with the requirements defined in NSTS 1700.7b, “Safety Policy and Requirements for Payloads Using the Space Transportation System”, NSTS 1700.7b ISS Addendum, “Safety Policy and Requirements for Payloads Using the International Space Station”, and NASA Technical Memorandum TM 102179, “Selection of Wires and Circuit Protection Devices for NSTS Orbiter Vehicle Payload Electrical Circuits”.

Power for the AMS-02 Payload is supplied from several sources dependent upon mission phase, as described in the following sections. For reference see Figure 5.12.2-1 and Figures 5.12.7-1 through 5.12.7-4.

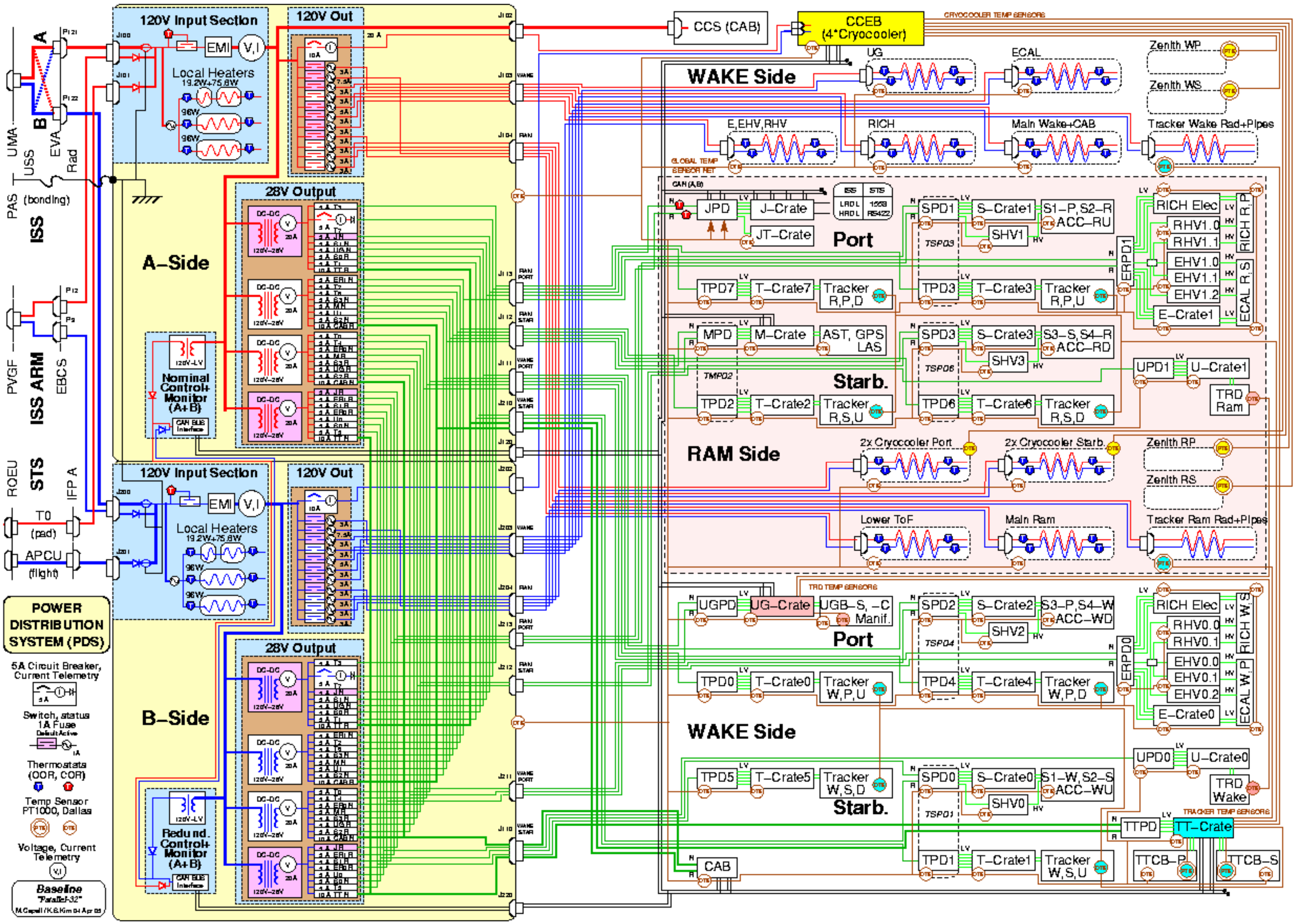


Figure 5.12.2-1 Payload Power Interfaces

5.12.2.1 Power Interface for Ground Operations in the STS

During ground operations, 120Vdc power is supplied via the T0 Umbilical, through the Remotely Operated Electrical Umbilical (ROEU) to the PDS to power experiment electronics. The GSE T0 power supply is a 3 kW Type B power supply per SSP 30482, Volume I, Rev. C. A separate 28 Vdc power feed, via the T0, through the ROEU is used to power a vent pump on the AMS-02 that allows the SFHe tank to vent the boil-off of the Helium during ground pre-launch operations until T-9 minutes. Although located on the AMS experiment, this vent pump is operated during ground operations only, and is not operated in flight. For safety purposes, structural integrity must be preserved. Just prior to deactivation of the Vent Pump prior to launch, the SFHe “Vent Valve” is commanded closed.

Following payload installation, roughly 650W of power is required for vent pump operation, operation of the four cryocoolers and for critical monitoring functions. During these periods, monitoring capability is supplied via both 1553 Bus and RS422 serial communications each routed through the T0 umbilical interface.

5.12.2.2 Ascent Power Interface on the STS

During Ascent, momentary power is required to open the SFHe Vent Valve. This valve must be opened prior to the Orbiter getting on-orbit, to allow venting of the boil-off Helium once the pressure in the Payload Bay drops below the operating pressure of the SFHe Tank. There are two means of ensuring that this vent valve opens, as discussed in the following paragraphs. Should the vent valve fail to open, burst disks will vent the He boil-off, thus preventing helium tank rupture, again discussed in the following paragraphs.

The vent valve must be operated during ascent when the tank is still experiencing acceleration, and when the exterior pressure within the payload bay is less than the He boil-off pressure within the tank. The SFHe tank contains a liquid-vapor phase separator called a “porous plug” at the vent line. This plug allows vapor to pass through, but no liquid. The SFHe vent valve must be opened with only He vapor against the “porous plug” at the initiation of flow to avoid a condition that can cause the porous plug to operate as a SFHe pump, which would speed the depletion of helium from the tank. To ensure that no liquid is against the porous plug, the vent valve and porous plug are located on the experiment in the direction of the acceleration vector of the Space Shuttle, and the valve is opened during powered flight.

A barometric switch on the AMS-02 is used as the primary signal to open the SFHe Vent Valve, and 28Vdc power from a Standard Switch Panel (SSP) is used to open the valve. AMS-02 SFHe Tank Valve Control Electronics receives 28 Vdc ascent power from the two powered maintained switches (S16 and S18) on 5A circuit breaker CB4 at the standard switch panel (SSP 2A) through connector J7 on Interface Panel A. Switch S16 is designated as the primary and S18 as the back-up 28 Vdc power feed. Two redundant, parallel switches are closed pre-flight, to provide this power. If there was a return of the AMS in the Cargo Bay due to an Orbiter contingency; AMS would request reconfiguration of the switches to the pre-launch configuration during De-orbit Prep activities; this is not a safety issue, but is an AMS-02 turnaround concern. This would allow the barometric switch to close the SFHe vent valve. The SSP switch power is limited to less than 5A by an upstream circuit breaker, CB4. This equipment is detailed in Table 5.12.2.2-1 and Figure 5.12.2.2-1.

TABLE 5.12.2.2-1 STANDARD SWITCH PANEL CONFIGURATION

ITEM	DEVICE TYPE	AMS-02 FUNCTION
CB4	Circuit breaker, 5 Ampere IN – Closed OUT – Open	IN: Applies orbiter pwr to switches S16 and S18 (Prelaunch/Ascent Configuration). OUT: Removes orbiter pwr from switches S16 and S18 (performed sometime after Post Insertion)
S16	Toggle switch, 2 positions (Maintained – Maintained) ON – Up Position OFF – Down Position	ON: Applies 28 VDC to AMS-02 Control Electronics Assy (Prelaunch/Ascent Configuration). OFF: Removes 28 VDC from AMS-02 Control Electronics Assy (performed on-orbit sometime after Post Insertion)
S18	Toggle switch, 2 positions (Maintained – Maintained) ON – Up Position OFF – Down Position	ON: Applies 28 VDC to AMS-02 Control Electronics Assy (Prelaunch/Ascent Configuration). OFF: Removes 28 VDC from AMS-02 Control Electronics Assy (performed on-orbit sometime after Post Insertion)

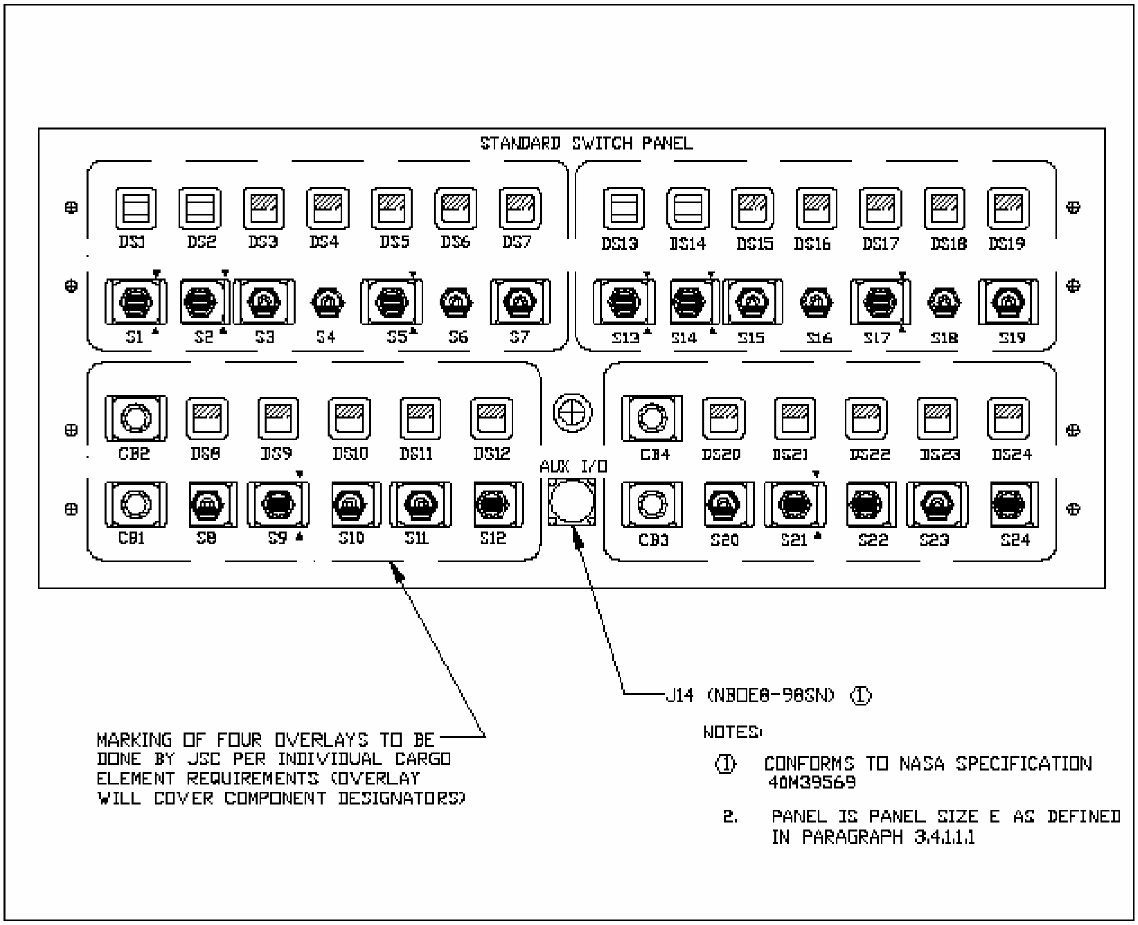


Figure 5.12.2.2-1 – Orbiter Aft Flight Deck Standard Switch Panel

The barometric switch is being selected to open the valve once the pressure in the Payload Bay drops below the operating pressure of the SFHe Tank (presently estimated at less than 15 mbar, or approximately three minutes into the flight).

As a backup, a time-tagged command from the Backup Flight System (BFS) General Purpose Computer (GPC) will issue a Discrete Output Low (DOL) to the Vent Valve Electronics to open the valve if the barometric switch has failed to do so. This time-tagged command will be set to a Mission Elapsed Time (MET) after the point at which the barometric switch should have opened the valve but while still in "powered flight". The STS has collected extensive data on Payload

Bay pressure during ascent, and this data will be used to determine the proper MET, that corresponds to this pressure, at which point the command will be issued.

Barometric switch selection is ongoing and the Vent Valve Control Electronics remain under design. As these elements are powered during ascent and descent, specific selection and design criteria have been used to ensure that they do not pose flammable atmosphere ignition sources. However, as the helium system is designed with burst disks, the operation of the vent valve is critical for mission success – to prevent the loss of the SFHe, but its function is not essential for safety.

5.12.2.3 Power Interface for On-Orbit Operations on the STS

While in the Shuttle payload bay, on-orbit 120Vdc power for the AMS-02 comes from two ISS provided Assembly Power Converter Units (APCUs) through the ROEU to the PDS. Up to a maximum of 2 kW can be drawn during Shuttle based operations to power experiment electronics. Since the cooling system for the AMS-02 consists of radiators (that will be mostly pointing at the PLB walls), cooling on the STS will be limited. A continuous power of approximately 650W is expected, with excursions up to 2 kW as environmental conditions allow. The magnet can not be charged while on-board the STS, as the ROEU provided power is routed solely to the B side of the Power Distribution System. As Sections 5.1.2, 5.12.2.5, and 5.12.3.2 explain, only side A of the PDS has power connectivity to the magnet charging circuits within the CAB.

The ROEU PDA is mounted on a boom that positions it such that it can interface the Orbiter side of the ROEU while the AMS-02 is mounted in the payload bay. The extension of the PDA on this boom extends out of the attached payload physical envelope for the AMS-02 ISS PAS location, as defined in SSP-57003 (It does not intrude into the adjacent envelope directly.). This boom is designed to be manually folded by an astronaut during an Extra-Vehicular Activity (EVA) if required by the addition of an adjacent PAS berthed payload or ISS equipment.. The astronaut will position himself at the EVA worksite by handrail that is located near the PDA, and will release the boom by extracting space qualified pip-pins. The boom will be folded down and locked in place, again by using the pip-pins. The power supply characteristics for the ROEU provided power are shown in Table 5.12.2.2.

TABLE 5.12.2-2 STS ROEU POWER SUPPLY CHARACTERISTICS

INPUT BUS	Internal BUS connection	PIN	Max Power [KW]	Current Rating	Lowest Current Limitation Level	Minimum Trip Decision Time	TYPE	CONNECTOR I/F	PDS connector
T0	A	4 x AWG12	1.8	14.7 A (1)	22 A (1)	100 msec (1)	--	IFPA P8	J101
APCU	B	3 x AWG8	1.8 3.6 (2)	14.7 A 29.4A (2)	22 A	100 msec	--	IFPA P1	J201

(1) These value are for reference only. The power supply will be a ground power provided by the KSC with performances similar to the APCU.

(2) (2) If two APCU in parallel are used

5.12.2.4 Power Interface for Extra Vehicular Robotics (EVR) Activities

Just prior to transfer activities, the AMS-02 is powered down, the APCUs are deactivated, and the ROEU is disconnected from the Payload Disconnect Assembly (PDA) attached to the AMS-02. The AMS-02 is grappled by the Shuttle Remote Manipulator System (SRMS) via a Flight Releasable Grapple Fixture (FRGF) attached to the payload. The FRGF has no power interface capabilities.

The SRMS maneuvers the AMS-02 for an Arm-to-Arm transfer to the Space Station Remote Manipulator System (SSRMS). The SSRMS grapples the payload via a Power and Video Grapple Fixture (PVGF) located on the opposing side of the AMS-02 from the FRGF. The PVGF provides pass-through ISS power from the SSRMS to the Electronic Berthing Camera System (EBCS) mounted on the AMS Passive Payload Attach System (PAS). The EBCS uses this 50 W of power to operate avionics that provide a video signal, which is returned to the crew compartment via the PVGF and SSRMS. The EBCS is used to align the payload and determine closure range during payload berthing operations. Additionally, the EBCS can pass through power from the PVGF to the AMS-02 payload. AMS-02 contains thermostatically controlled heaters that may utilize some or all of this power to maintain the payload temperature within design limits. The amount of power required is dependant on environmental conditions during transfer and the length of time the payload spends on the SSRMS.

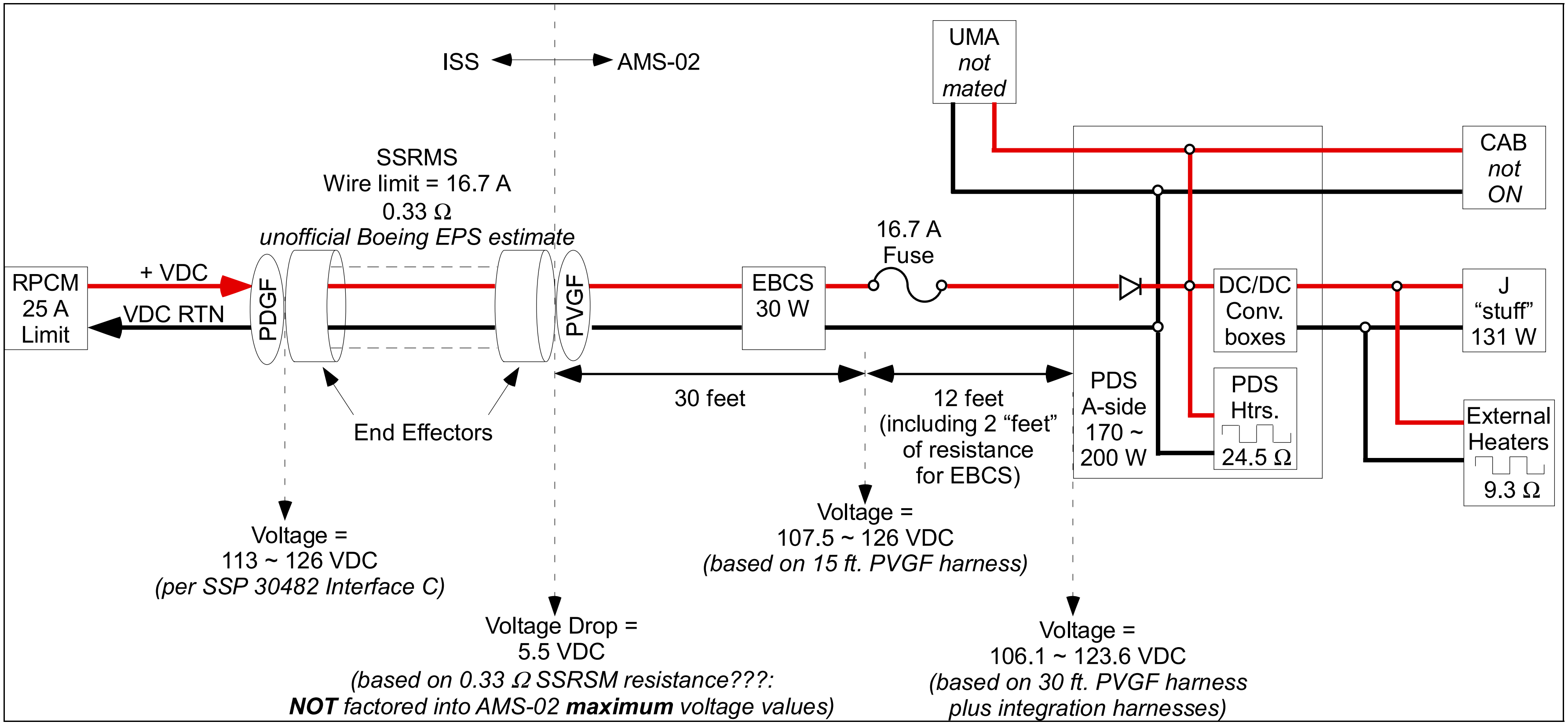
The nominal power supply characteristics, provided in *SSP 42004, Mobile Servicing System (MSS) to User (Generic) Interface Control Document Part I*, for the PVGF provided power are shown in Table 5.12.2.3. Due to SSRMS payload bus wire sizing, and worse case thermal analysis for these wires, the SSRMS payload bus operating current has been limited to 16.7 Amps. Detailed design analysis by the developer of the PDS, Carlo Gavazzi Space (CGS), shows that for all SSRMS based operations, and over the entire range of possible input voltages, the AMS-02 payload will comply with this current limit. The upstream Remote Power Control Module (RPCM) that supplies SSRMS payload power bus is a Type II RPCM, which limits the power at 25 Amps. It is therefore required to further protect the SSRMS payload power bus wiring, which cannot handle 25 Amps, by installing a properly de-rated fuse before the input of the AMS-02 PDS, as shown in Figure 5.12.2.4-1, AMS-02 SSRMS Operations Power Schematic.

TABLE 5.12.2-3 ISS PVGF TO USER ELECTRICAL INTERFACE PARAMETERS

Circuit Name	INTERFACE V_{range} (volts) 3	Operating Current (amps)	Overcurrent Protection
PVGF1	107.5 to 126	0 to 16.7	1, 2
PVGF2	107.5 to 126	0 to 16.7	1, 2

NOTES:

1 Protection is equivalent with SSP 30263:002, Type II RPCM Standard ICD
2 Protection is equivalent with SSP30263:002, Type VI RPCM Standard ICD.
3 Minimum voltage includes 1 volt drop across the PVGF harness.



Note: The SSRMS payload back-up bus and PDS A-side are shown for AMS-02 schematic completeness, even though the CAB will not be ON during SSRMS Ops. The SSRMS payload prime bus and PDS B-side (not shown) are identical except they have no connectivity to the CAB.
This also includes a 16.7 Amp fuse, that will be required by the PSRP because the SSRMS wiring cannot withstand the entire 25 Amps available from the RPCM.
Finally, 30 W has been added as the power consumed by the EBCS avionics.

Figure 5.12.2.4-1 – AMS-02 SSRMS Operations Power Schematic

5.12.2.5 Power Interface for ISS Operations

All power and data services for the AMS-02 payload are provided through an Umbilical Mechanism Assembly (UMA) mounted to the Payload Attach Site. ISS provides two 120 Vdc power feeds, each controlled by Type II RPCM (25A). AMS-02 is capable of operating from either or both buses; however, magnet charging requires that Bus A be active because the Cryomagnet Avionics Box (CAB) is connected to Bus A only. The choice of going with only one Bus for this operation was made for simplicity and reliability; otherwise a bus switcher would have been required, a potential single point failure. In the event of a loss of the ISS power input bus that feeds Bus A, an EVA operation can be performed to switch EVA connectors for Bus A and Bus B, thus re-establishing the capability to charge the cryomagnet. It should be noted that Bus A and Bus B have independent PDS output sections to preclude cross linking. During magnet charging operations a maximum power of 2.3 kW will be required near the end of the charging cycle for the Cryomagnet Avionics Box (CAB) and critical monitoring equipment only. Once charging is complete, the charging system is isolated from the magnet, and the remaining power is devoted to detector operation. The power supply characteristics for the UMA provided power are shown in Table 5.12.2.4.

TABLE 5.12.2-4 ISS UMA POWER SUPPLY CHARACTERISTICS

INPUT BUS	Max Power [KW]	PIN	Current Rating	Lowest Current Limitation Level	Minimum Trip Decision Time	TYPE	CONNECTOR I/F	PDS connector
A	3	3 x AWG8	25 A	27.5 A	31 ms	RPCM II	EVA PANEL P121	J100
B	3	3 x AWG8	25 A	27.5 A	31 ms	RPCM II	EVA PANEL P122	J200

5.12.3 Power Distribution System (PDS)

The PDS, the yellow shaded box in Figure 5.12.2-1, consists of four distinct sections: 120 Vdc Input; 120 Vdc Output; 28 Vdc Output; and Low Voltage Control and Monitor. The bus to bus isolation of the 120Vdc outputs is provided by the end-subsystem, by either DC-to-DC or AC converters, or relays. The isolation for all other outputs is provided internally to the PDS by DC-to-DC converters. The PDS has two independent "channels" side A and side B (Figure 5.12.3-2), which have four identical subsections. The only difference between the two channels is that side A is the only side that provides power to the CAB for magnet charging, as described in Section 5.12.3.2.

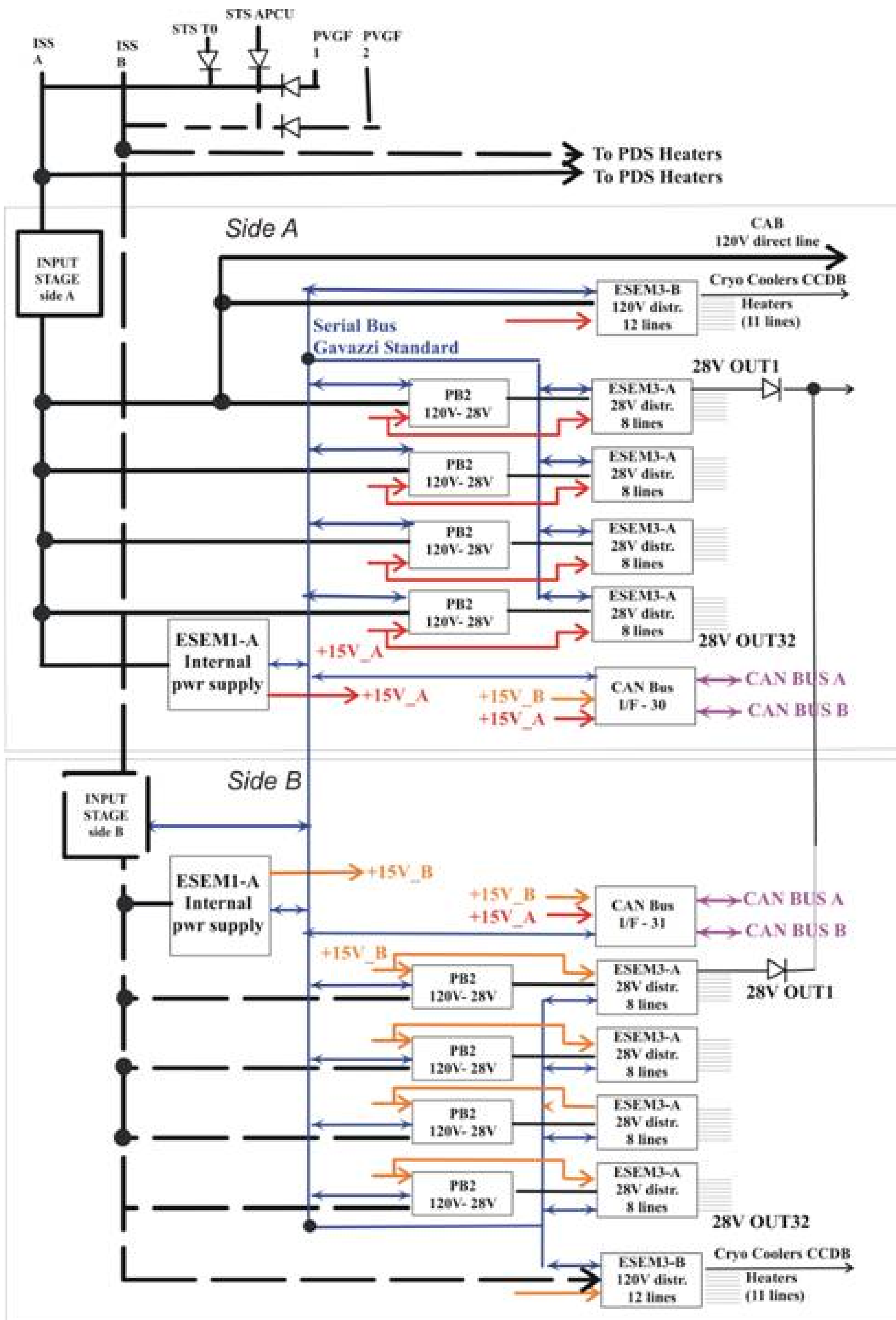


Figure 5.12.3-2 AMS-02 Power Distribution System, Sides A and B

The interfaces for the individual sections shown in Figure 5.12.3-2 are detailed in Table 5.12.3-1.

TABLE 5.12.3-1 PDS SECTION INTERFACE DETAILS

<table>
<tr><th colspan="3">PDS SIGNAL & POWER INTERFACES</th></tr>
<tr><td colspan="2">INPUT SECTION</td><td></td></tr>
<tr><td>ISS</td><td>Power I/F input</td><td>• 120V Feeder A
• 120V Feeder B</td></tr>
<tr><td>STS</td><td>Power I/F input</td><td>• 120V Feeder APCU
• 120V Feeder T0</td></tr>
<tr><td>BCS (PVGF)</td><td>Power I/F input</td><td>• 120V Feeder PVGF 1
• 120V Feeder PVGF 2</td></tr>
<tr><td colspan="2">EMI FILTER</td><td>• EMI I/F</td></tr>
<tr><td colspan="2">INPUT TELEMETRY</td><td></td></tr>
<tr><td>INPUT TELEMETRY</td><td>Signal I/F</td><td>(Via internal serial I/F to the CAN BUS module)
• INPUT CURRENT
• INPUT VOLTAGE</td></tr>
<tr><td colspan="2">INTERNAL POWER SUPPLY SECTION</td><td></td></tr>
<tr><td rowspan="2">ESEM 1-A</td><td>Power I/F</td><td>15V Internal Power Supply</td></tr>
<tr><td>Signal I/F</td><td>(Via internal serial I/F to the CAN BUS module)
• ON/OFF DC/DC CONVERTER
• DIGITAL Board Status Monitoring
  • OK/NOK
  • OVERTEMP
  • DC/DC 1 OVERCURRENT
  • DC/DC 2 OVERCURRENT
  • DC/DC 1 MAIN ON/OFF
  • DC/DC 2 MAIN ON/OFF
  • MAIN POWER ON
  • DIGITAL TEST OUT
• ANALOGUE Board Monitoring
  • TEMPERATURE
  • ANALOG REFERENCE VOLTAGE
  • MAIN POWER VOLTAGE</td></tr>
<tr><td colspan="2">120V OUTPUT SECTION</td><td></td></tr>
<tr><td>DIRECT OUTPUT</td><td>Power I/F</td><td>• 120V Feeder to CCS in CAB</td></tr>
<tr><td>ESEM 3-B</td><td>Power I/F</td><td>• OUT 1 for AMS heaters
• OUT 2 for AMS heaters
• OUT 3 for AMS heaters
• OUT 4 for AMS heaters
• OUT 5 for AMS heaters
• OUT 6 for AMS heaters
• OUT 7 for AMS heaters
• OUT 8 for AMS heaters
• OUT 9 for AMS heaters
• OUT 10 for AMS heaters
• OUT 11 for AMS heaters
• OUT 12 CCEB (Cryocoolers)</td></tr>
</table>

TABLE 5.12.3-1 PDS SECTION INTERFACE DETAILS (CONTINUED)

PDS SIGNAL & POWER INTERFACES		

	Signal I/F	(Via internal serial I/F to the CAN BUS module)
		• ON/OFF OUTLET Command
		• DIGITAL Board Status Monitoring
		  • OK/NOK
		  • OVERTEMP
		  • OUTLET STATUS (ON/OFF)
		  • OUTLET TRIP STATUS (only for CCEB line)
		• ANALOGUE Board Monitoring
		  • TEMPERATURE
		  • OUTLET CURRENT (only for the CCEB line)
		  • ANALOG REFERENCE VOLTAGE

120V TO 28V CONVERSION SECTION		
PB2	Power I/F	• 28V OUTPUT to the ESEM 3-A distribution board

	Signal I/F	(Via internal serial I/F to the CAN BUS module)
		• ON/OFF DC/DC CONVERTER Command
		• DIGITAL Board Status Monitoring
		  • OK/NOK
		  • OVERTEMP
		  • DC/DC CONVERTER STATUS (ON/OFF)
		  • INPUT OVERCURRENT
		  • OUTPUT OVERVOLTAGE
		• ANALOGUE Board Monitoring
		  • TEMPERATURE
		  • 28V OUTPUT VOLTAGE
		  • ANALOG REFERENCE VOLTAGE

ESEM 3-A	Power I/F	• 8 x 28V output lines
		  • out 1 to 7 @ 5A each
		  • out 8 @ 10A

	Signal I/F	(Via internal serial I/F to the CAN BUS module)
		• ON/OFF OUTLET Command
		• DIGITAL Board Status Monitoring
		  • OK/NOK
		  • OVERTEMP
		  • OUTLET STATUS (ON/OFF)
		  • OUTLET TRIP STATUS
		• ANALOGUE Board Monitoring
		  • TEMPERATURE
		  • OUTLETS CURRENT
		  • ANALOG REFERENCE VOLTAGE

DIGITAL I/F SECTION		
CAN BUS I/F	Signal I/F	• CAN BUS I/F • PDS INTERNAL BUS I/F • DIGITAL Command to the boards • ANALOGUE ACQUISITIONS of the boards telemetry • DIGITAL ACQUISITIONS of the boards status

The design of the PDS is such that the power conversion and distribution is performed by four different printed circuit board types. These types, and quantities per sides A and B, along with current protection details, are described in Table 5.12.3-2.

TABLE 5.12.3-2 PDS PRINTED CIRCUIT BOARD & CURRENT PROTECTION DETAILS

Board Type	Quantity	Function	Outputs	Current Protection	Notes
ESEM3-A	4 per side	Distribution of the 28V secondary voltage, provided by the PB2 modules, to AMS-02 Payloads	8	MOSFET Current limiter, trips @ 130% nominal current between 5 and 6 msec. • Channels 1 - 7: 5 Amp • Channel 8: 10 AMP	Eight output channels individually: • Equipped with MOSFETs for ON/OFF switching • Provided with status and current measurement circuitry
ESEM3-B	1 per side	Distribution of the 120V provided by the power input BUS to supply AMS-02 heaters and the CCEB device.	12	• Channels 1 - 11: Fuses, derated (see Table 5.8.3-3) • Channel 12: MOSFET Current limiter, trips @ 130% nominal current between 5 and 8 msec.	Twelve outlets that are independently: • Equipped with MOSFETs for ON/OFF switching • Protected by fuse is series with MOSFET except for outlet 12 where current limiter circuit is used • Provided with status monitor circuitry • For outlet 12 (CCEB) a current telemetry circuit is added Considering the maximum bus value of 126V, the current rating of each outlet is set to a nominal output current of one of the follow: • 1.4A (>50% derating) • 3.2A (>50% derating) • 2.3A (>50% derating) • 10A (Channel 12)
PB2	4 per side	120Vdc to 28Vdc converter module.	1	Redundant DC-DC converters with current limiting and breaking element comprised of two power MOSFETs (2N7225) connected in parallel	Current intervention threshold is fixed at 9A±0.4A (the timing of the protections is lower than 1ms to guarantee for trip coordination with upstream characteristics). If the current rises above this threshold, the MOSFETs are switched off bringing the gate voltage to zero.
ESEM1-A	1 per side	Provides for the generation of the internal power line (15V/5A) required for PDS operation.	1 @ 15VDC 1 @ 5VDC	Redundant DC-DC converters with current limiting - current breaking element comprised of one power MOSFET (2N6798) trips @ 200% nominal current.	Each DC/DC converter includes an in-rush current limiter and an over current circuitry with, •a PWM controller, • a power cell based on half bridge topology, • input under voltage detection circuit, • input EMI filter

The fuses for the ESEM3-B printed circuit board 120 VDC outputs are detailed in Table 5.12.3-3.

TABLE 5.12.3-3 PDS 120 VDC FUSE DETAILS

DESCRIPTION	PROC.SPEC	SUPPLIER	P/N-ID.CODE	EM Notes
Fuse 3A FM12 style fuse (subminiature, high performance)	MIL-PRF-23419	AEM - USA	P600L-135-3	3A fuse Nework code: 251003
Fuse 7.5A FM12 style fuse (subminiature, high performance)	MIL-PRF-23419	AEM - USA	P600L-135-7.5	7A fuse Nework code: 251007
Fuse 5A FM12 style fuse (subminiature, high performance)	MIL-PRF-23419	AEM - USA	P600L-135-5	5A fuse Nework code: 251005

The PDS has associated heaters, which serve to raise the PDS temperature to its minimum operation limit when power is applied to the AMS, as shown in Figure 5.12.3-3.

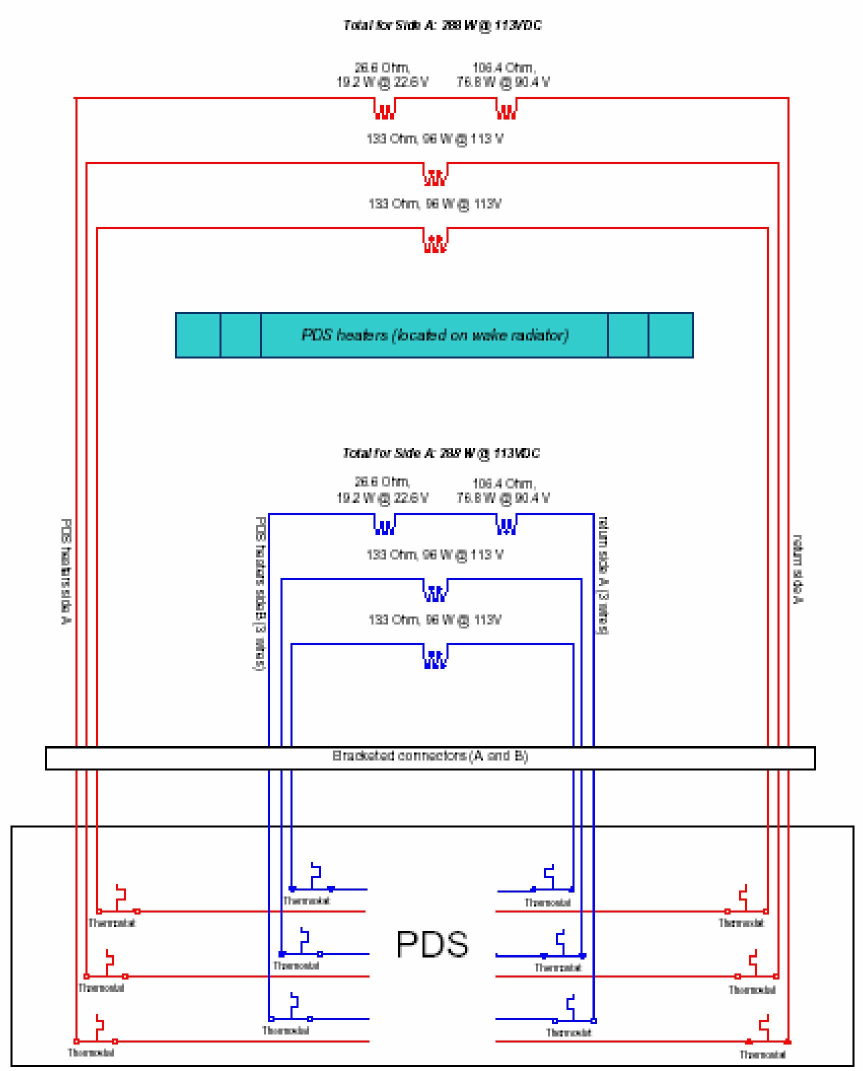


Figure 5.12.3-3 PDS Internal Heaters

The PDS is located on the Main Wake Crate Rack very close to the Passive Umbilical Mechanism Assembly (Figure 5.12.3-4).

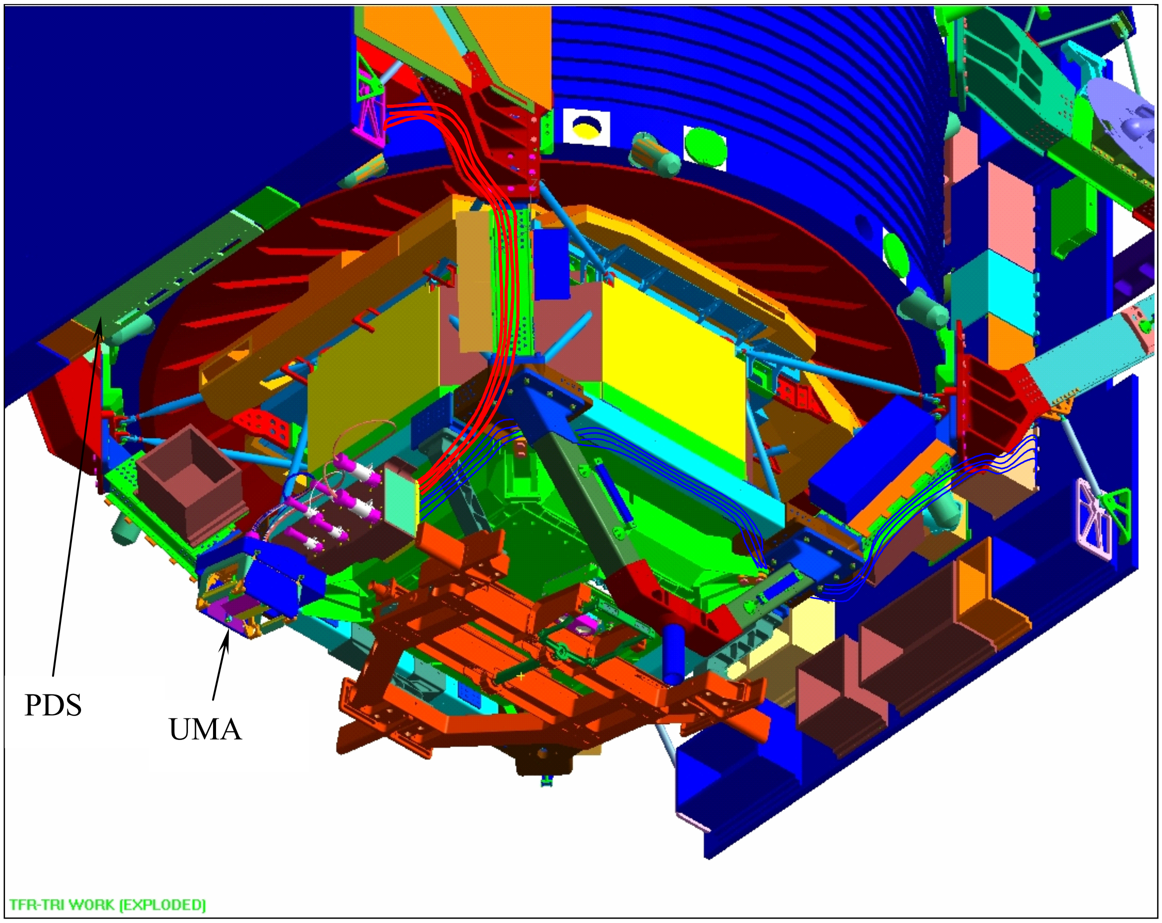


Figure 5.12.3-4 Location of the PDS and UMA on AMS-02

The PDS shall comply with the bonding requirements as defined in SSP 57003 Attached Payload Interface Requirements Document, Revision B, paragraph 3.2.2.4.2 between:

- Different parts of the equipment chassis
- Connector receptacles and equipment chassis/connector brackets
- Equipment chassis and bond strap
- Bond strap and structure

The method proposed for the PDS bonding to the AMS structure is Bond Strap using one (1) attachment point on the structure. The attachment point location is on the rear wall. All PDS metallic components and surface shall be bonded in order to preclude accumulations of static charge inside the PDS Box.

The bonding diagram for the PDS, representative of Side A or Side B, only, is shown in Figure 5.12.3-5.

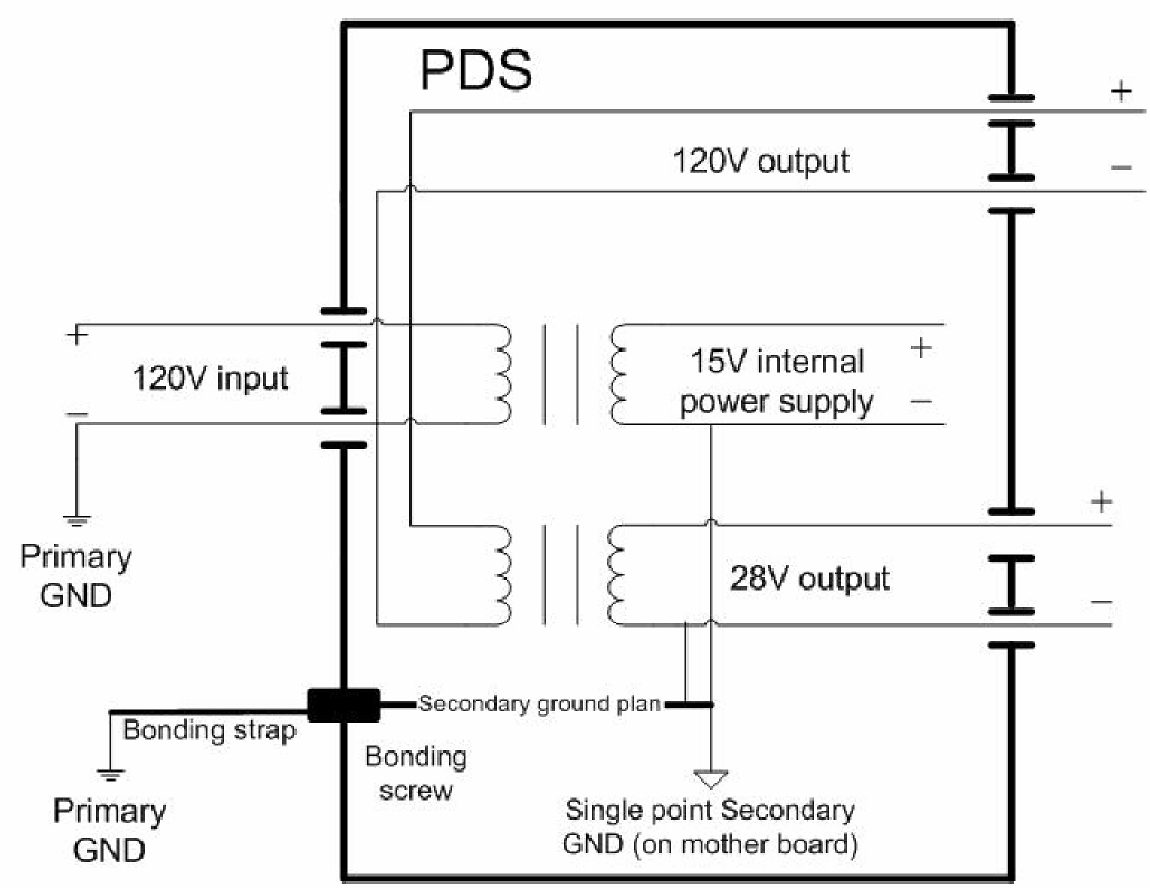


Figure 5.12.3-5 Bonding Diagram of the PDS, representative of Side A or Side B, only

The PDS avionics, with respect to the overall grounding system, shall be based on the following concepts as per SSP 30240 Space Station Grounding Requirements, Revision C:

- The primary electrical power shall be isolated from PDS chassis by a minimum of 1MΩ
- Implementation of a galvanic isolation between the primary power bus and all the secondary internal or distributed powers
- All the secondary power references are connected together and to the PDS structure in a single point represented by a bonding stud located on one PDS wall

- The secondary power references shall be isolated from the PDS chassis by a minimum of 1MW when the single point bonding is not connected.

All the parts of the box housing the PDS electronic are electrically connected together in order to offer a low impedance path. The PDS box is equipped with a bonding stud. A copper bus bar shall be placed inside the PDS in order to collect the single point bonding from the Power Boards. The copper bus bar shall be isolated from the PDS wall. The copper bus bar shall be connected internally to the PDS bonding stud by means of ring terminals and the PDS Bonding Stud shall be connected to the AMS structure by means of a bond strap. The bonding stud will be connected to the AMS support structure in such a manner:

- To conduct electrical faults current without creating thermal or electrical hazard
- To minimize differences in potential between all equipment

The mechanical box will operate as a shield against the internally generated emissions and the externally generated emissions.

The functions of the four subsections of the PDS are described in detail in the following sections.

5.12.3.1 PDS 120 Vdc Input Section

The 120Vdc Input Section is designed to receive power from three sources, and dependent on mission phase these three source powers are supplied from either T0 or APCUs via the ROEU, the PVGF or the ISS UMA power sources. The inputs use diode protection or connector protective covers to prevent crew or ground personnel from potential exposure to “hot-pins”.

As described earlier, during ground operations, this power may be supplied via the T0 umbilical (for normal operations); and the APCUs for end-to-end type testing with power supplied through the ROEU. During Shuttle flight operations, power is supplied solely via the APCU interface. The ROEU Payload Disconnect Assembly (PDA) does not provide a “protective cover” to prevent incidental contact with hot pins or sockets after disconnection from the active half. Therefore, diode protection is provided for the ROEU power feeds to prevent power feeds from the SSRMS and the ISS UMA from being present on the ROEU PDA.

For transfer operations on the SSRMS, power may be supplied by either feed via the PVGF interfaces. Standard ISS Operations Procedures dictate only one or the other feed from the SSRMS will be active at any time. While the EBCS will use this power to operate camera avionics, AMS-02 will use the feed-through power from the EBCS to operate thermostatically controlled heaters while the payload is on the SSRMS. Ideally, this operation will be relatively short (entire transfer should take less than 4 hours); and AMS-02 will be thermally conditioned prior to transfer, so no heater power should be required. The PVGF does not provide a protective cover to prevent incidental contact with hot pins or sockets when not connected to the SSRMS. Therefore, diode protection is provided for the PGVF power feeds to prevent power from other sources being present on the PVGF connector.

Once mated to the ISS (following deactivation of PVGF power and activation of ISS power via the UMA), the AMS-02 will be capable of operation from either or both ISS Buses. As stated earlier, Magnet Charging Operations requires that Bus A be activated. The UMA passive half does include a protective cover to prevent incidental contact with "hot-pins" and therefore precludes the need for additional diode protection.

Internally to the PDS, these power source feeds are combined into the two internal PDS buses and EMI Filters are used for compatibility with ISS Complex Impedance and EMC requirements. Voltage and Current measurements are provided within this "input section" to determine overall power consumption.

PDS "box-level" thermostatically controlled heaters are provided to ensure the PDS maintains operational thermal limits. There is a lockout feature that prevents operation of the PDS if it is not within operational thermal specifications when power is applied. Only these heaters operate until the PDS operational lower limit is reached, after which the distribution circuitry is activated. The heaters have two thermostats in series (one in the return leg of the heaters as demonstrated in Figure 5.12.3-3). All heaters and thermostats are redundant to accommodate either the A or B power feed. Following activation, internal electronics power consumption is expected to be sufficient to maintain thermal limits without requiring additional heating.

Note: A "Global Temperature Sensor Network" is used: to monitor box temperatures across the entire experiment, ensure that each box is activated only after operating temperatures are achieved; and to determine when the Solid State Power Controllers (SSPCs) can be opened to disable the heaters.

5.12.3.2 PDS 120 Vdc Output Section

For each 120 Vdc output, isolation is provided by the end-subsystem, by either DC-to-DC converters or relays. 120 Vdc feed-through power from the PDS includes outputs to the CAB, the Cryocooler Electronics Box (CCEB), and heaters (8 zone heaters and 4 Cryocooler heaters).

The 120 Vdc output from the PDS to the CAB includes no internal PDS circuit protection (other than wire sizing to meet ISS power requirements). A current sensor is provided to monitor the current to the CAB. This feed is used solely for magnet charging operations, described in Section 5.1.2. No matter what the source of 120 Vdc power, the design of the PDS is such that this power can be delivered from ISS Power Bus A only. However via an EVA the ISS power inputs A and B may be switched after arriving to the AMS-02, providing magnet charge capability redundancy in the event that input from ISS Power Bus A is lost.

The 120 Vdc output power to the CCEB is provided by either or both ISS Power Bus A and/or B. The PDS does include SSPCs (rated for 8A) for over-current protection. Current measurements for these feeds are provided for downlink.

Bus isolation of the heater outputs from the PDS is provided by the operation of two independent heater circuits (one for each power feed). Thus, ISS Power Bus A feeds the “A” heaters and ISS Power Bus B feeds the “B” heaters independently. All of the heater power is delivered “on demand” to the thermostatically controlled heaters. Application of power to both buses can result in both heater sets operating or the SSPCs can be used to deactivate either or both heater circuits. Zone and cryocooler heaters outputs from the PDS are current limited to between 3A and 7.5A by the SSPCs.

5.12.3.3 PDS 28 Vdc Output Section

The 28 Vdc Output Section provides isolation from the 120 VDC input for all 28 Vdc outputs via DC-to-DC Converters. This output section provides the bulk of the power to operate the Detector and Command and Data Handling Avionics. As a general rule, power from these outputs is routed to an xPD (subsystem Power Distribution Box) for powering of the x-Crate electronics and the detectors.

The 28 Vdc Output Section receives power from either of the internally generated 28 Vdc Buses, and 5 Amp SSPCs are used for power management and circuit protection. Therefore each output can be controlled to operate from either bus. The outputs of the SSPC from each bus are connected exclusively via diodes to their respective load. Voltage and current measurements are provided from the DC-to-DC converters and current measurements are provided at each SSPC for downlink.

5.12.3.4 PDS Control and Monitor Section

The Control and Monitor Section provides isolation for the low-voltage power system via DC-to-DC Converters (voltage and current measurements provided for downlink). This section is used primarily for autonomous control and monitoring of the PDS to ensure activation only after the minimum operating temperature is achieved, and ground control and monitoring of the all PDS outputs for power management. Communications with this section are maintained via a Controller Area Network (CAN) Bus Interface used for low-rate data and command interfaces. All PDS telemetry is passed through this section to the Main Data Computers for downlink.

5.12.4 Cryomagnet Avionics Box (CAB)

The CAB (Figure 5.12.4-1) is designed to perform all control and monitoring functions for the Cryomagnet Subsystem (including SFHe Tank and Vacuum Case). The CAB consists of four sections: the Cryomagnet Current Source (CCS); the Cryo Controller and Signal Conditioner (CCSC); the Cryomagnet Self Protection (CSP); and the Power Switches (PS).

The CAB is located on the Unique Support Structure (USS) very close to the current input port of the Vacuum Case to minimize the length of the Cryomagnet Current Leads (Figure 5.12.4-2).

High Voltage Isolation is provided at all inputs to the CAB from the ISS side to prevent passing any high-voltage that could be developed during a multiple fault “unassisted” quench back to the ISS power or data systems. Isolation for the 120Vdc line (feed thru from PDS) is performed via DC-to-DC Converters in the CCS (Section 5.12.4.1). Analysis has shown that the maximum voltage that could be achieved during an “unassisted” quench is 5.5kV. 8kV isolation is provided at all these points to ensure margin. The unassisted quench is an off-nominal scenario, and would result in damage to the CAB and the magnet that would render them unusable, but not create a safety hazard. The one fault “assisted” quench would prevent these voltage levels from arising and protect the CAB and the magnet for mission success.

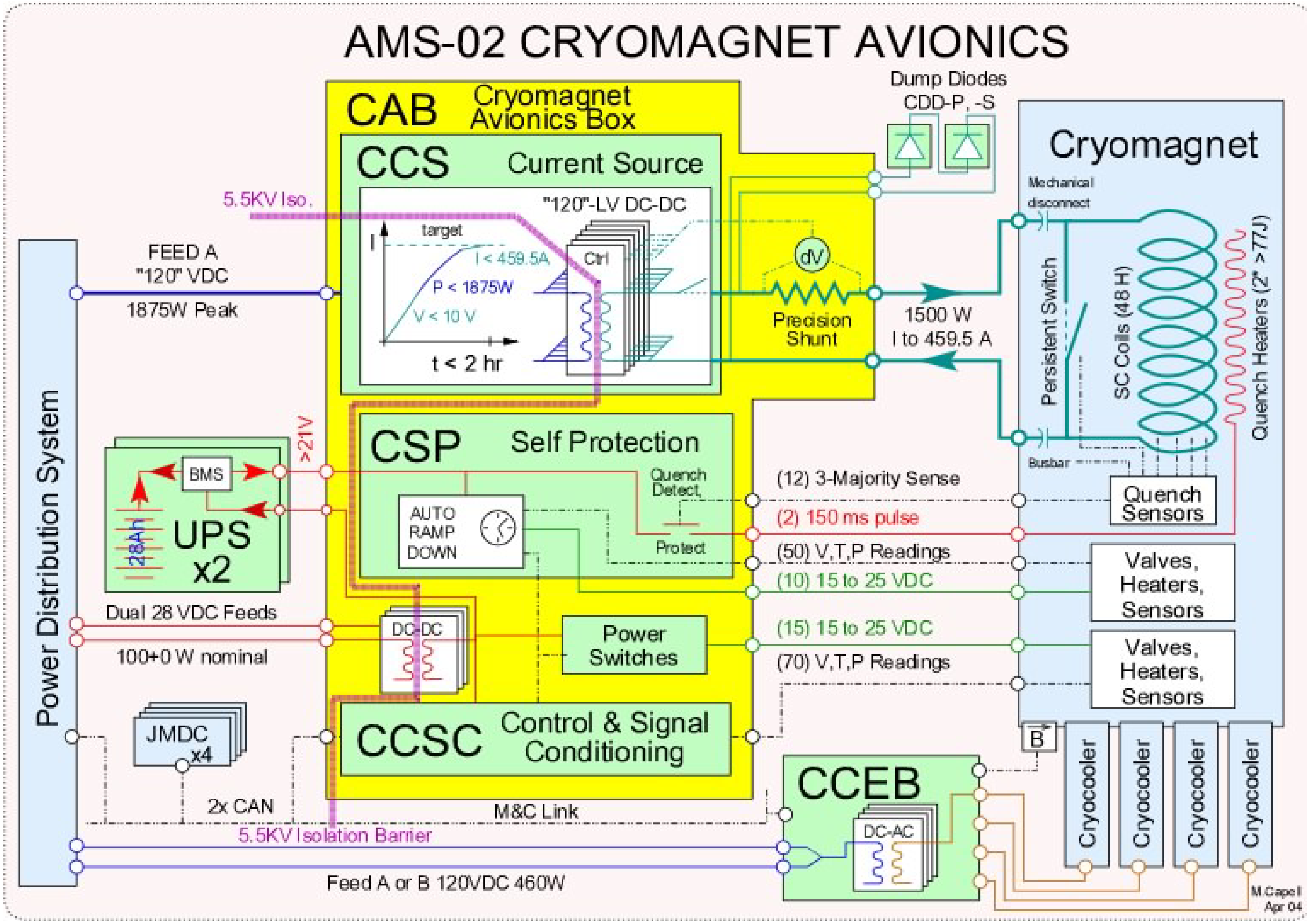


Figure 5.12.4-1 Schematic of the AMS-02 Cryomagnet Avionics Box (CAB) and Cryomagnet

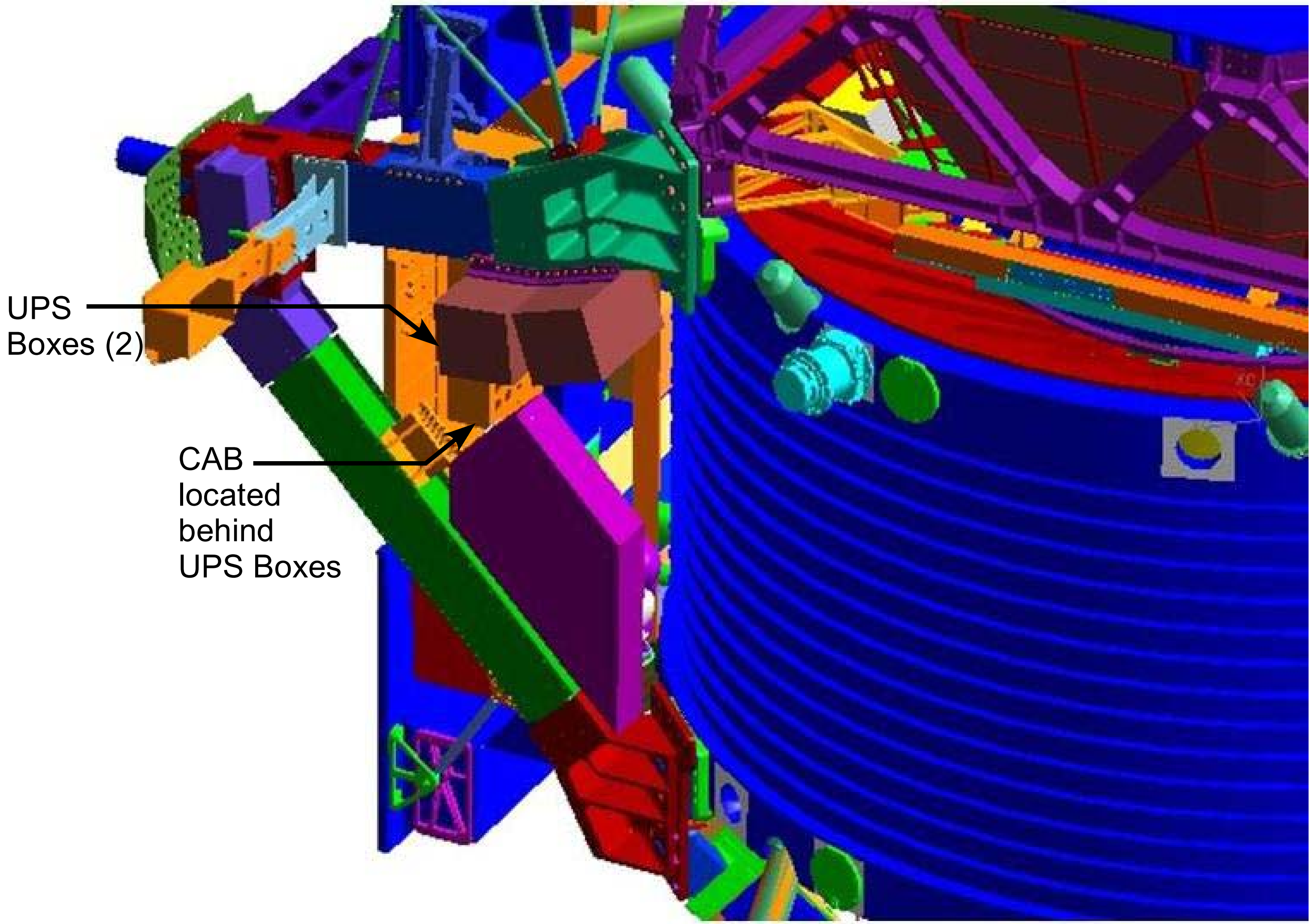


Figure 5.12.4-2 Cryomagnet Avionics Box (CAB) on the USS-02

The bonding diagram for the CAB is shown in Figure 5.12.3-3.

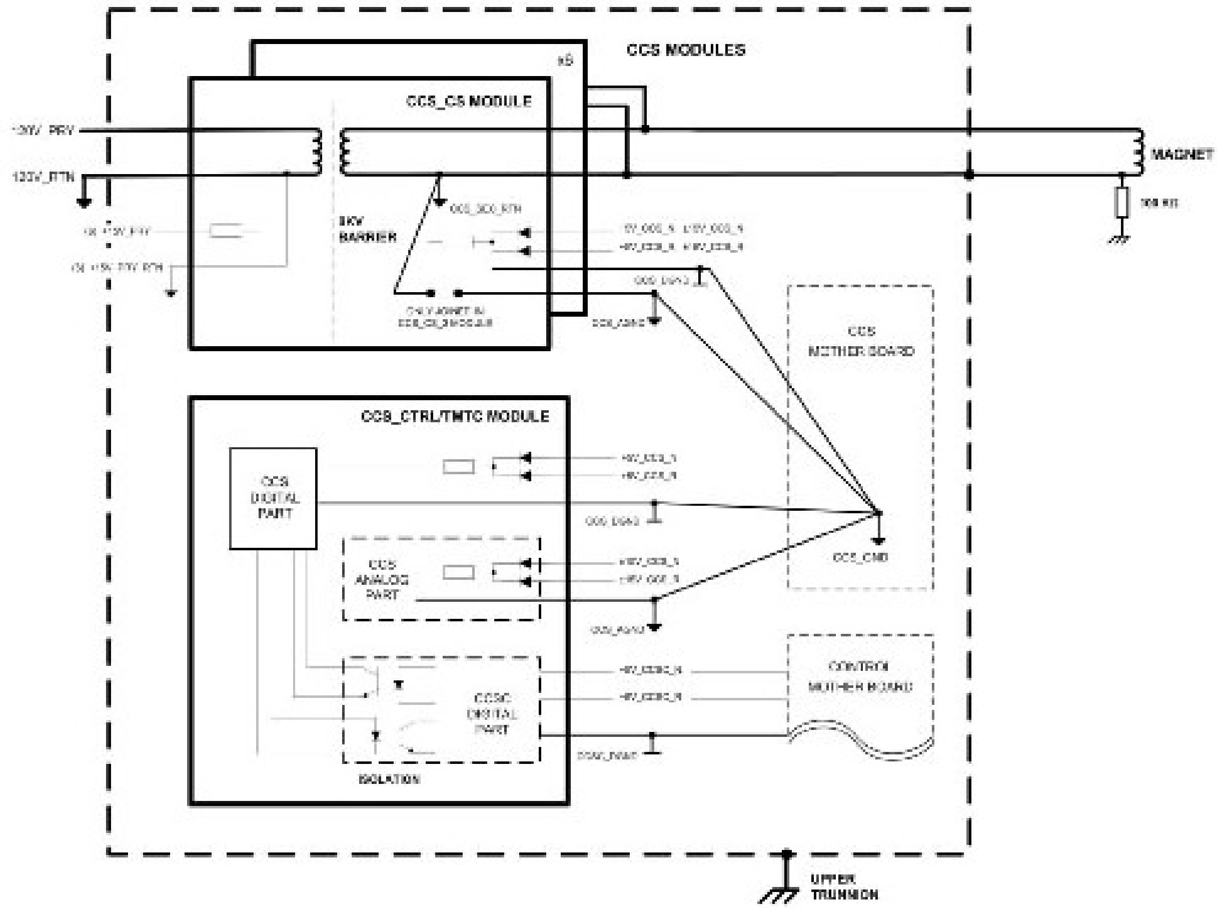


Figure 5.12.4-3 Bonding Diagram of the CAB

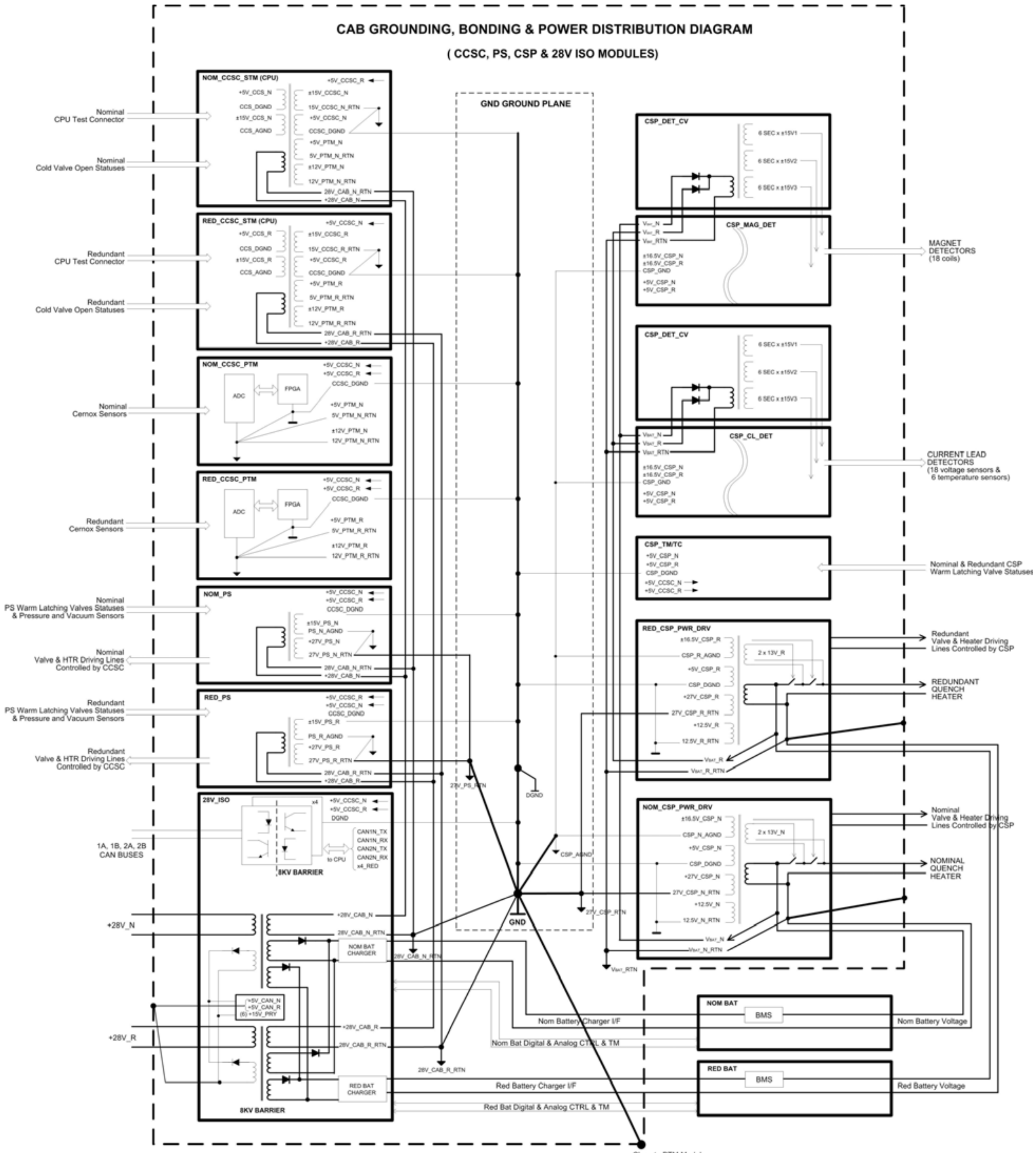


Figure 5.12.4-3 Bonding Diagram of the CAB (continued)

The CAB design includes three protection barriers in series in order to not permit an actual current of the magnet higher than 459A. The protection barriers are:

1. Software protection (digital value)
2. Field Programmable Gate Array (FPGA) protection (digital value)
3. Hard-wired control electronics protection circuitry

The software protection prohibits the electronics which controls the ramping to be set to an end of ramp current greater than 459A. From a worst case analysis, the setting error (the difference between the current value targeted by the electronics and the actual value of the current produced including errors in both translating the target current into a DC level and the measurement of the resulting current) is less than 3.5A. The final SW limit value will be decided after testing of the flight unit, but will be about 455.33A. This barrier avoids continuous operation of the hardwired protection of the third barrier.

The second protection is implemented in firmware at the FPGA level. This protection barrier would be engaged in the case that failures of the CPU software or hardware lead to the request for a target current that is too high. The FPGA protection limit is 457A. This second barrier avoids also the continuous operation of the third barrier in case of internal failure of the active CPU.

The third protection is implemented in a majority voting configuration (three conditioning circuits of the control circuitry). The nominal value of this third protection is 455.5A. In case of failure, and in worst case analysis, the current limit of the third protection will again depend on the setting errors from the protection circuitry error (±1.5A) and the control electronics error (±2A). This represents an inaccuracy of ±3.5A for the third protection barrier.

Figure 5.12.4-4 illustrates the three barriers in series. The third barrier really represents the safety barrier. This never permits any magnet current larger than 459A. The control electronics uses a majority voting configuration with three conditioning circuits in parallel. As seen in the diagram, the majority voting topology is obtained by joining the three conditioning circuits in one set of electronics. This electronics is implemented using double transistors for the three circuits and therefore providing a single point failure free topology. Therefore, any transistor in short or open circuit will be tolerated by the majority voting electronics without propagating the failure.

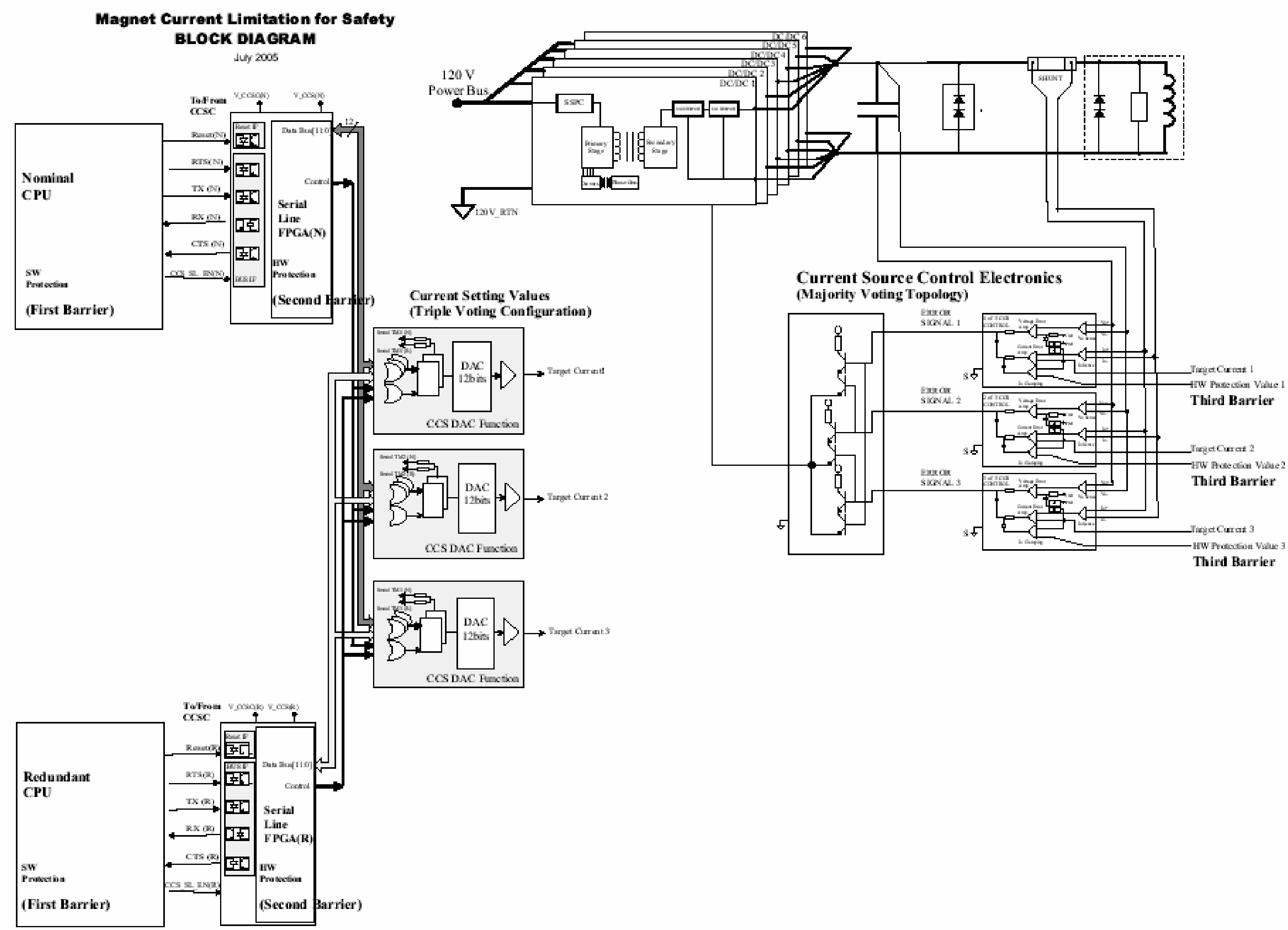


Figure 5.12.4-4 CAB Magnet Current Limitation Barriers

5.12.4.1 Cryomagnet Current Source (CCS)

The 120 Vdc Power input (feed through from the PDS) is routed solely to the CCS. A DC-to-DC converter at the input to the CCS provides isolation for this Power Bus. The 120 Vdc power is required only for magnet charging. All other sections of the CAB are operated with 28 Vdc from the PDS.

The 120 Vdc input is limited to a maximum of 1875 W for power management. Power supplied to the DC-to-DC converter is controlled by Opto-Isolating feedback from the DC-to-DC converter output with a power switch and pulse width modulation of the input.

To charge the magnet, the Semiconductor switch on the charging circuit (reference Figure 5.12.2-1) is closed, and power is supplied to the transformer input. The current is slowly ramped up over a period of approximately 1.5 hours to 459 Amps. Current during charge and discharge operations is monitored using a 500A shunt. The connection from the CCS to the magnet is made via three pairs of AWG 2/0 wires. Once full operating current is reached, the Persistent Switch is closed (the switch consists of a pair of super-conducting wires – "closed" by cooling them down to superconducting temperatures). With the persistent switch closed, 459 A is running through both sides of the circuit (the magnet side and the charger side). To avoid ripple currents through the persistent switch, the current on the charger side is slowly reduced to zero. Once the current on the charger side is depleted, the Semiconductor Switch is opened, and the Charging System is disconnected from the Magnet Circuit.

Note: Mechanical disconnects on the Charging Leads for the magnet (not indicated in Figure 5.12.4-3, see Figure 5.12.4-1) are used to provide thermal isolation from the outside environment during all operations except charging and discharging. Prior to charging or discharging, the mechanical disconnects must be connected, and then disconnected after the operation is complete. Additional detail of this hardware is included in the Cryomagnet Description, Section 5.1.

If an event occurs that necessitates a power down of the magnet, the system is designed to perform a nominal "ramp down" function. The nominal ramp down is the most acceptable method for powering down the magnet without the potential for substantially decreasing the endurance of the magnet. To perform a ramp down, the mechanical leads are connected and the persistent switch is opened (by allowing it to warm to a non-superconducting state), diverting the current from the magnet through the Cryomagnet Dump Diodes (CDDs) (Figures 5.12.4-1 & 5.12.4-5). The connection from the magnet is to the CAB with three pairs of AWG 2/0 wires, and then on to the CDD, with a loop of one AWG 2/0 wire. This cable routing is shown in Figure 5.12.4-6. The energy from the magnet is dissipated in the form of heat through the CDD chain. The CDD consists of six sets in series of three diodes in parallel that are used solely for the purpose of dissipating the stored energy of the magnet. These dump diodes are located on the two wake-side sill trunnion joints (three sets on each joint), which were selected for their large thermal mass. The CDDs are protected by a metal cover to prevent incidental contact by ground personnel or crew. The total time required to dissipate the magnet energy is estimated to be 80 minutes.

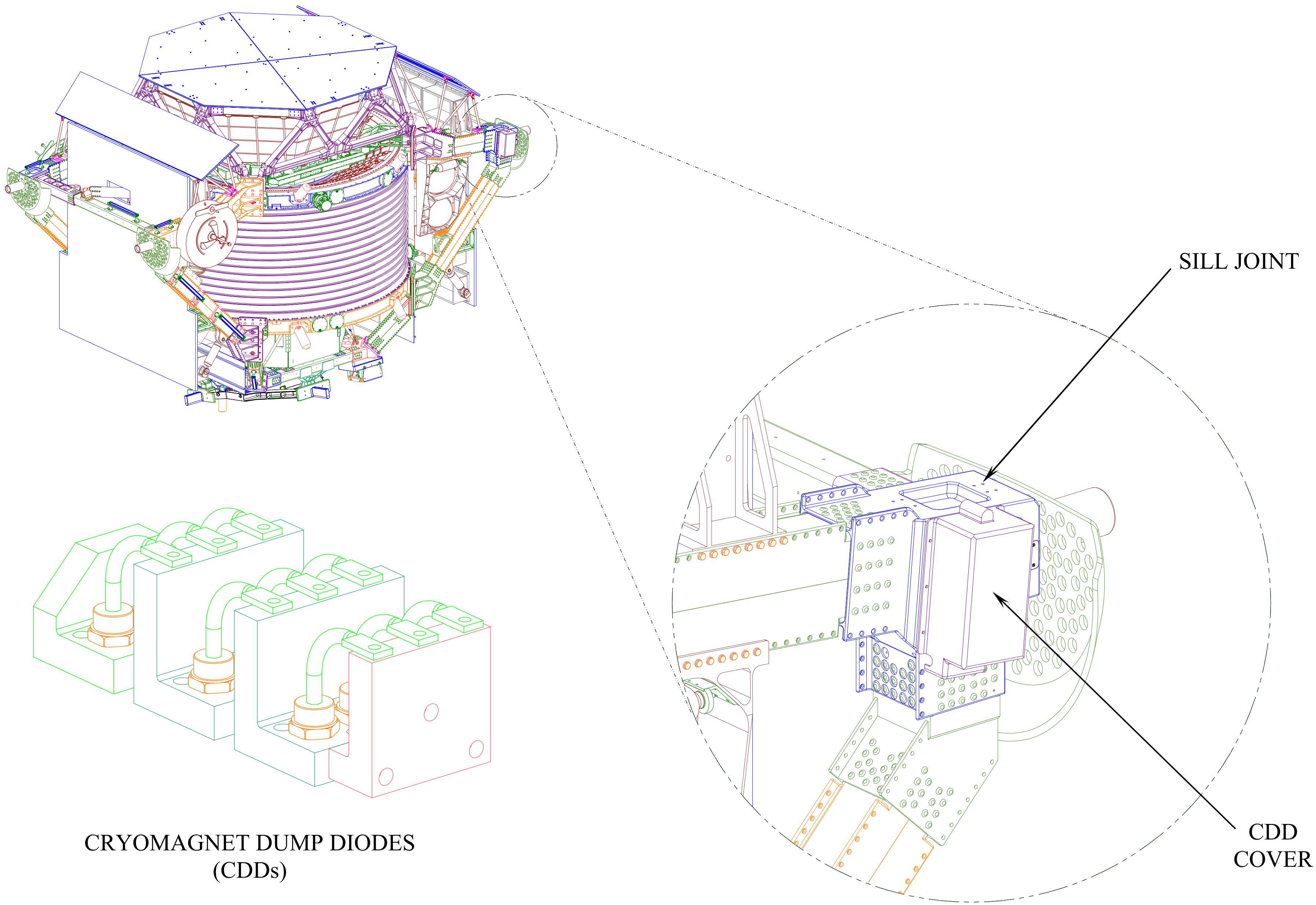


Figure 5.12.4-5 Cryomagnet Discharge System

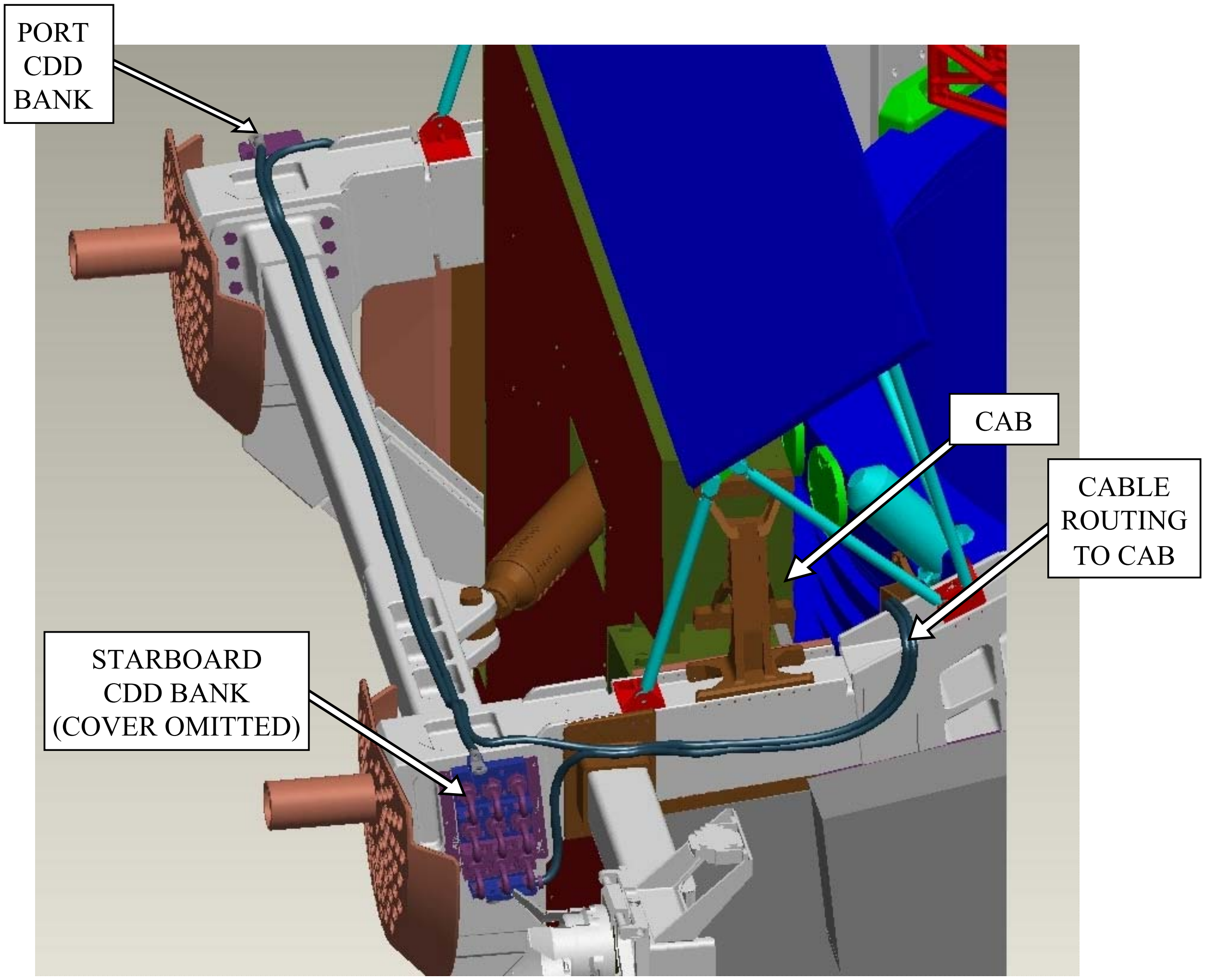


Figure 5.12.4-6 Cryomagnet Discharge Diode Cable Routing

5.12.4.2 Cryomagnet Control and Signal Conditioning (CCSC)

The CCSC provides the interface between the AMS-02 Main Data Computers (MDCs) and the Cryomagnet. The CCSC is responsible for:

- reception of commands from the MDCs
- transmission of telemetry to the MDCs
- commanding of the CCS
- control of the Cryomagnet auxiliary functions (i.e. heaters, valves, etc.)
- monitoring of the CCS, Cryomagnet, and CAB operating parameters and status

The CCSC also performs system fault detection and management functions, formatting of telemetry, and data storage for system status. The CCSC is required to interface with the Uninterruptible Power Source (UPS).

5.12.4.3 Power Switches

The power switches control the 28 VDC power supply to valves and cryogenic heaters. With the exception of the power switches controlled directly by the CSP, the power switches are galvanically isolated from the 28 VDC power bus.

5.12.4.4 Cryomagnet Self Protection (CSP)

Super-conducting magnets, such as the one utilized by AMS-02, may develop a condition where a portion of the coil begins to rise above super-conducting temperatures. When this condition occurs, the section of wire affected begins to develop resistance, and the current running through this resistance begins to heat the wire rapidly. This eventually leads to dissipation of the magnet energy (in the form of heat) within the magnet, and is referred to as a magnet quench. This condition is highly undesirable from a mission success standpoint because resulting unbalanced magnetic forces in the different sections of the magnet may cause it to deform, making it unable to be recharged to the maximum field or even to return to a superconducting state, thus preventing the recharging of the magnet. This is a possible mission success critical failure, not a safety issue. Alterations in the magnetic field have already been accounted for in the safety assessment for nominal field strengths.

To protect the magnet from this condition, referred to as an unassisted quench, electronics have been designed that will detect the initiating condition and apply heat quench evenly throughout the magnet coils, causing the magnetic field to dissipate uniformly. This will prevent the heating from being isolated to a small section of the magnet, which could become damaged if the quench was uncontrolled. By performing an assisted quench, mission success criteria can be maintained. The Cryomagnet Self Protection (CSP) section (Figure 5.12.4-7) of the CAB was developed to detect a change in voltage across a coil and perform this assisted quench.

The CSP contains quench detection electronics that monitor the status of the magnet coils to determine if a quench condition is starting to occur. To perform this function, redundant voltage measurements are taken across each coil. If a quench condition is imminent, a voltage will develop across the affected coil. When the CSP detects a change in voltage, the quench protection electronics issues a command to the Uninterruptible Power Source (UPS) to provide a pulse of at least 45A to quench heaters located throughout the magnet. The pulse, for a duration of 150 ms, is required to raise the entire magnet up to a non-superconducting state. This spreads the quench throughout the magnet and prevents isolated heating that could result in degraded performance.

The quench heater chains are redundant and supplied by two separate UPS systems. The chains are routed to alternate coils throughout the magnet. Both heater chains are nominally used by the CSP to control a quench, however either chain independently is sufficient to protect the magnet coils from deformation.

It is important to note that the CSP system is required only for mission success. Failure of the CSP does not constitute a safety hazard. The magnet is designed to withstand the forces that would be generated by an unassisted quench (see also the Cryomagnet description, Section 5.1).

The CSP provides additional functions (Figure 5.12.4-7) to protect the magnet during off-nominal conditions. A “watch dog” timer, powered by the UPS, is continuously counting down. Periodically the timeout is reset via external command to about 8 hours. In the event of a power loss, or the loss of communication to the AMS-02 payload, the timeout is not reset and if power or communications are not restored to the AMS within the eight-hour period, the timer will trigger the CSP Control Electronics to initiate the nominal ramp down function, discharging the magnet. During the eight hour period and the ramp down, the UPS will continue to power the Quench Detection Electronics, and maintain the capability to perform an assisted quench (if necessary) until the magnet is completely discharged. The CSP, showing the cross-strapping configuration between the power busses coming from the PDS and the two batteries of UPS, is shown in Figure 5.12.4-7.

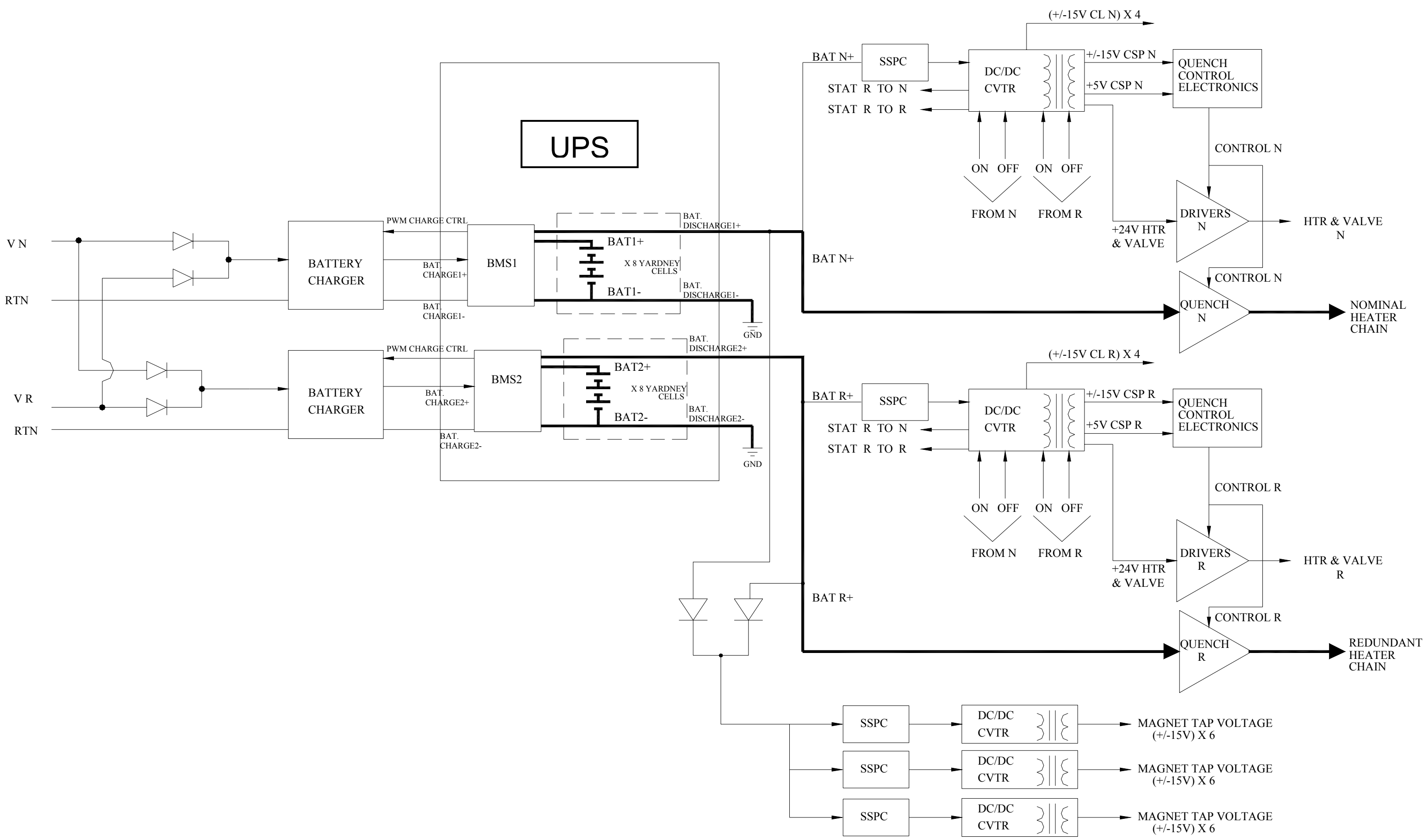


Figure 5.12.4-7 Functional Block Diagram of the Cryomagnet Self Protection (CSP)

5.12.4.5 CSP Uninterruptible Power Source (UPS)

The UPS consists of dual redundant 28 Amp-hour (A-h) Lithium Ion Batteries and a Battery Management System (BMS) for each, developed by Yardney/Lithion Corporation, Pawcatuck, CT. Each battery consists of eight cells in series to generate the required nominal 28 Vdc for the system. To ensure mission success during loss of ISS power or communication, the UPS is required to supply power for the watchdog timer function, quench monitoring functions, nominal ramp-down at watchdog timer rundown, and initiation of a quench pulse of at least 45 A for 150ms anytime during the sequence.

Figure 5.12.4-8 shows the protection circuitry for the CAB Battery Charger Electronics (BCE), providing isolation between the UPS and PDS. The CAB BCE design includes the following protection electronics:

- Two double diodes in a cross-strapping configuration of the nominal and redundant 28Vdc primary power busses coming from PDS unit.
- SSPC (Solid State Power Conditioner), implemented by means of an Latching Current Limiter (LCL), which opens in case of failure.
- The HV power transformer barrier, which provides galvanic isolation between the electronics on primary side and the electronics on secondary side.
- The control electronics to provide the fit current to the battery, and also includes a power transformer with galvanic isolation.
- The blocking diode included in the BMS Battery Management System Electronics, which only permits the current way in only one direction.

All the above-mentioned protections included in the CAB BCE guarantee no propagation of failure to the ISS or any other unit, such as the PDS, which provides the 28Vdc primary power busses.

On the other hand, the CSP electronics design includes the following protection electronics between UPS and the loads (quench heaters, magnet valves):

- Two switches in series to power the quench heaters. These switches are only closed during 150ms of time required for the quenching sequence.
- SSPC (Solid State Power Conditioner), implemented by means of an LCL Latching Current Limiter, which opens in case of failure.

- The power transformer barrier, which provides galvanic isolation between the electronics on secondary side and the electronics on the load side.
- Two switches in series to open or close the valves.

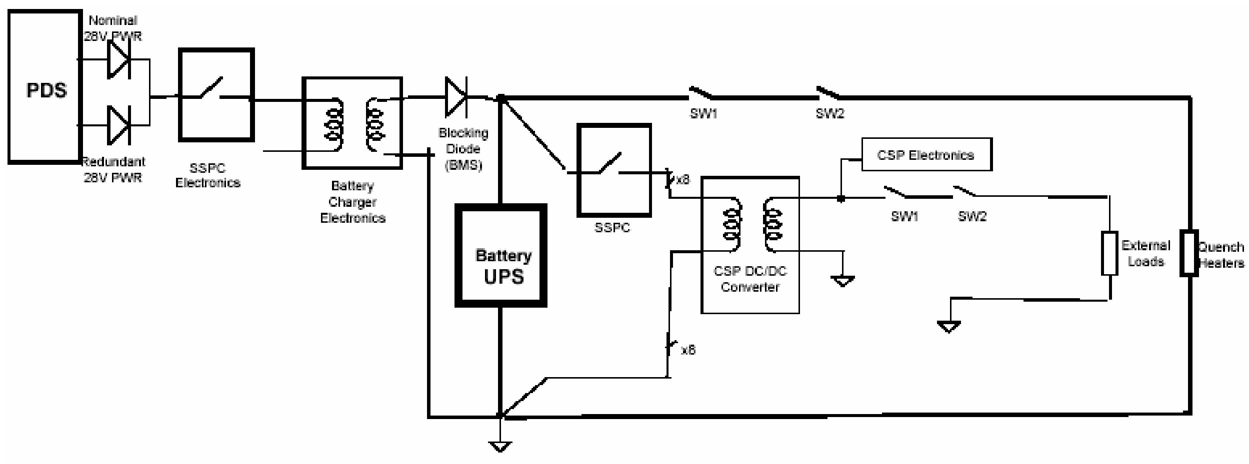


Figure 5.12.4-8 PDS to UPS Interface Diagram

5.12.4.5.1 <u>Cells/Brick</u>

The cells are a prismatic design, weigh approximately 2 pounds, and have an operating temperature range from –30° C to +50° C. The mechanical design of the cells is heritage from the Mars Lander program, certified for flight on an expendable launch vehicle (ELV) but not flown. The electrolyte for the cells is an upgrade from the Mars Lander design and is currently used in the B2 Bomber program. It was selected for its broad operating temperature range.

The overall packaging for each cell is shown in Figure 5.12.4-9.

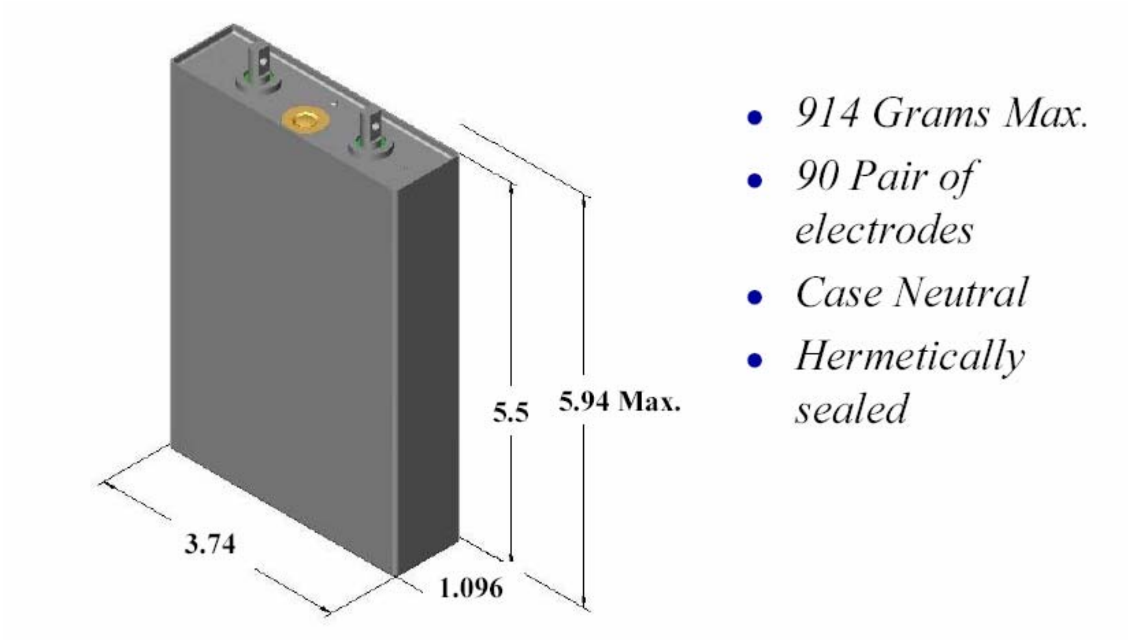


Figure 5.12.4-9 UPS Battery Cell Packaging

Cell features are shown in Figure 5.12.4-10.

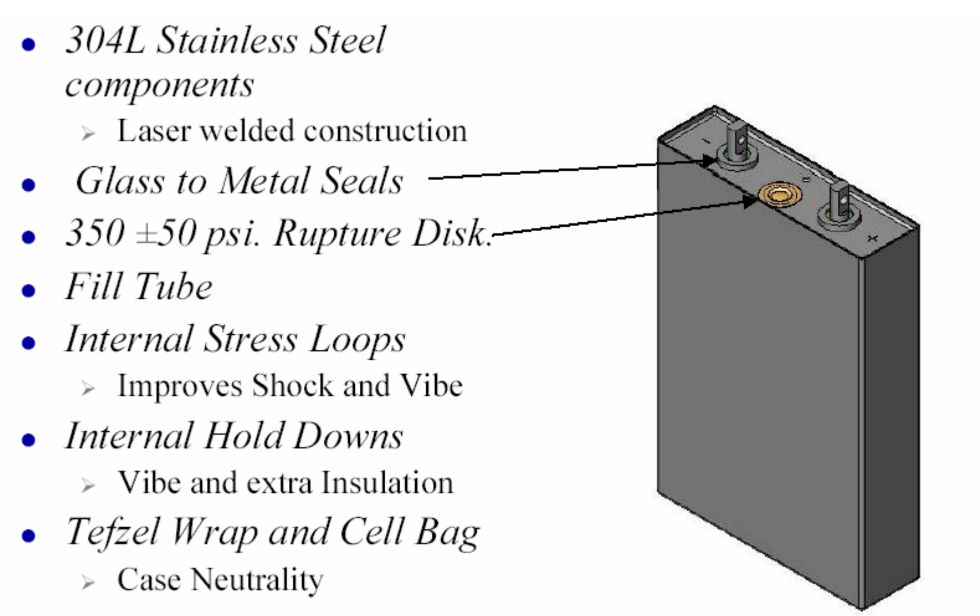


Figure 5.12.4-10 UPS Battery Cell Features

An exploded view of the UPS battery cell is shown in Figure 5.12.4-11.

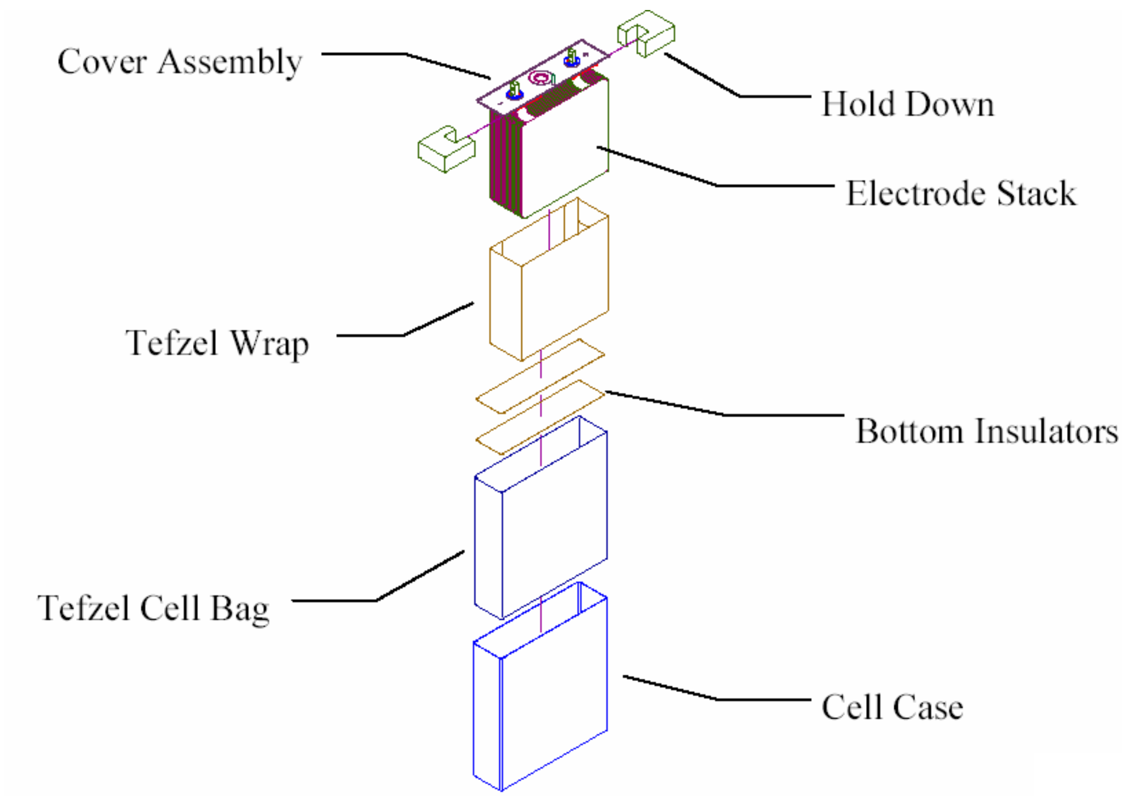


Figure 5.12.4-11 UPS Battery Cell, Exploded View

The cells are delivered in a configuration, called a brick (Figure 5.12.4-12). The brick contains eight cells encased in a bracket (with two endplates), designed for a nominal preload of approximately 1100 lb. The preload tolerates minor swelling of the individual cells, but offers a fixed volume for mounting.

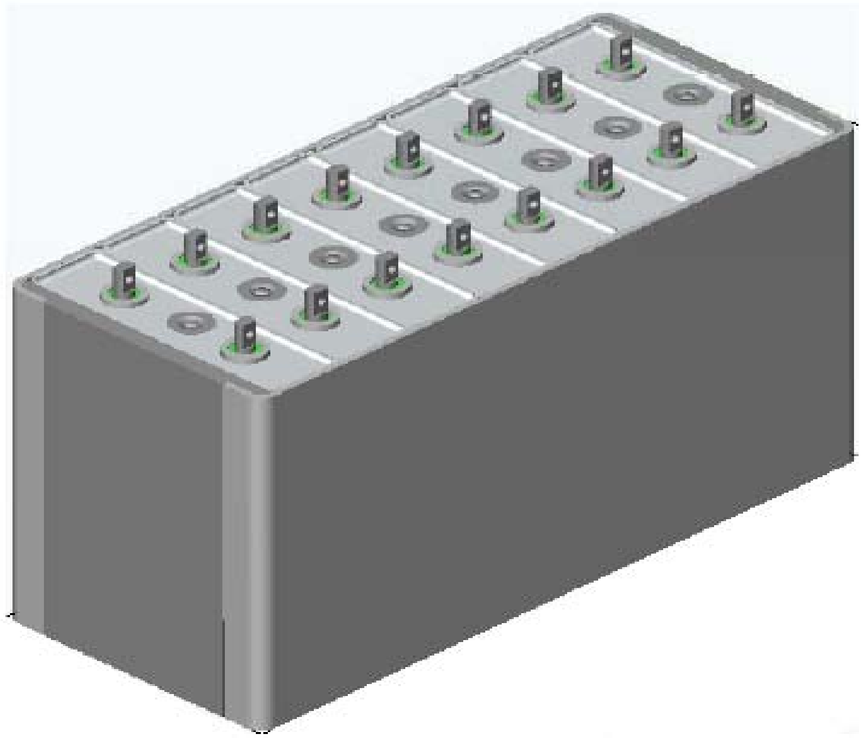


Figure 5.12.4-12 UPS Battery Configuration "Brick"

5.12.4.5.2 Battery Management System

The Battery Management System (BMS), Figure 5.12.4 – 13, consists of four independent circuit boards and is designed to have the primary responsibility for battery condition (along with good design). The four boards consist of: a master controller board, two monitor/equalizer boards, and a protection/regulator board.

The BMS master controller board communicates with the two monitor/equalizer boards to obtain cell voltage and temperature. The master controller board uses this information to calculate the battery state of charge (SOC) for use in the charge algorithm and to control the battery pack cell equalization. In case of a critical hardware failure, such as loss of communication to the monitor equalizer boards, the master controller board determines this condition and activates the protection board or charger switch.

The two monitor/equalizer boards monitor cell voltage and pack temperature. They perform cell equalization on each charge cycle by resistively bypassing any cell with a voltage in excess of a predetermined maximum. The bypass current is dissipated through a resistor array on the board.

The master control board determines when the voltage condition is reached and activates the bypass. The master control board also determines when a cell voltage is exceeding allowable safety limits and activates the Protection and/or Charger switch as well.

The protection/regulator board is used to disconnect the pack from the load during fault conditions that include high cell temperature, low cell voltage and high current.

Additionally, a charger switch will disconnect the battery from the charger in cases of high cell temperature, high cell voltage or if the charger becomes uncontrollable. The switch will open in the case of a critical hardware failure, such as loss of communication to the monitor equalizer boards. The master controller board determines these conditions and sends the signal to the protection board or charger switch. The protection board employs multiple parallel metal-oxide-silicon field effect transistors (MOSFET) to carry the battery load current. Upon the occurrence of a short circuit the protection switch will open within 100µsec (TBR) to isolate the battery from the short circuit condition.

The BMS contains both hardware and software inhibits to control potential safety issues such as overcharge, over-discharge, over-temperature, and over-current. Regardless of failure of any of these items, a catastrophic failure of the battery is not credible. The safety settings are:

- Over Charge: If a cell charge exceeds 4.2 V for more than 2 to 3 seconds, software disconnects the battery from the charger. Exceeding 4.3 V on a given cell for 100 µsec causes a hardware inhibit to pull the battery off-line. Even if both of these inhibits malfunction, the battery charger is current limited to 3A and at this rate of charge the cells will vent before presenting any hazard.
- Over Discharge: If a cell voltage drops below 2.5 V for 3-4 seconds, software disconnects the battery from the discharge circuitry. A drop below 2.15 V for 200 µsec causes a hardware inhibit to disconnect the battery from the discharge circuitry.
- Over Temperature: Exceeding 80° C on a battery pack for 3-4 seconds causes software to disconnect the battery from the Charger.

- Over Current: A current draw of 80 A for more than 2-3 seconds causes a software inhibit to disconnect the battery from the discharge circuitry. A hardware inhibit initiates if 170 A is seen for 100 µsec.

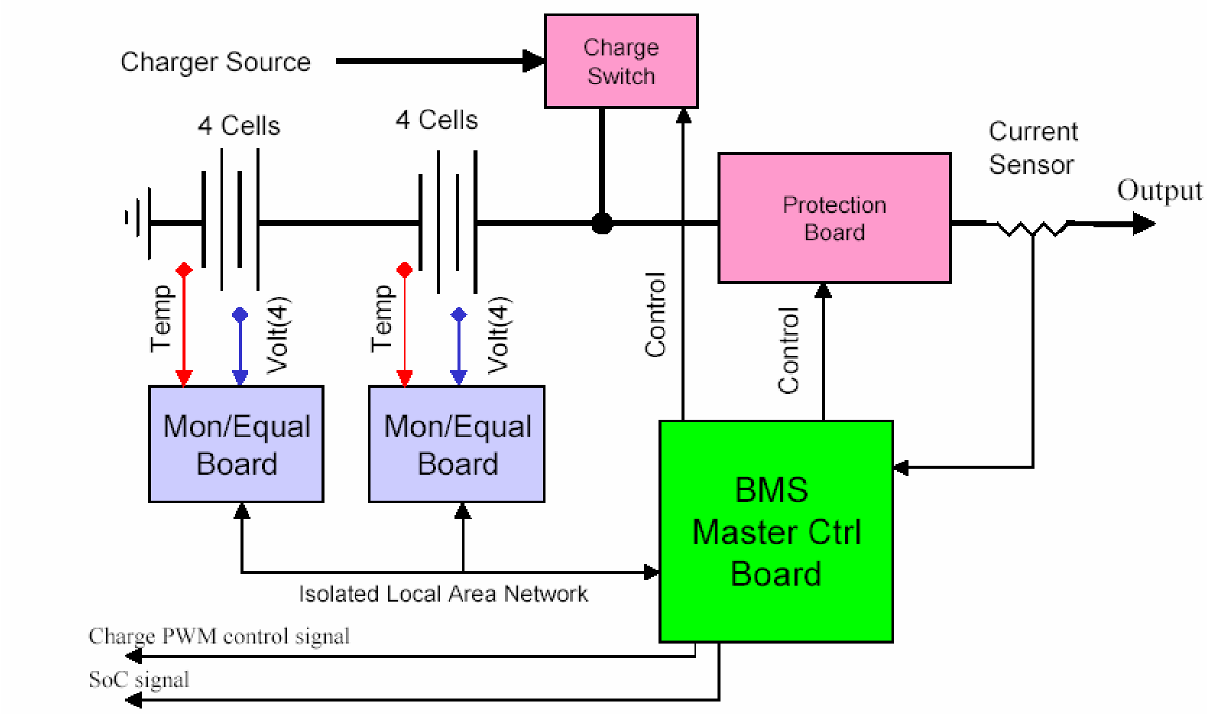


Figure 5.12.4-13 Battery Management System

5.12.4.5.2 <u>UPS Mechanical Packaging</u>

Two sets of bricks and BMSs are mounted into a UPS box, apiece, which provide further containment and protection from MM/OD, as shown in Figure 5.12.4-14. Both UPS boxes are mounted to the USS in proximity to the CAB and the input port on the Vacuum Case to decrease line resistance (Figure 5.12.4-15).

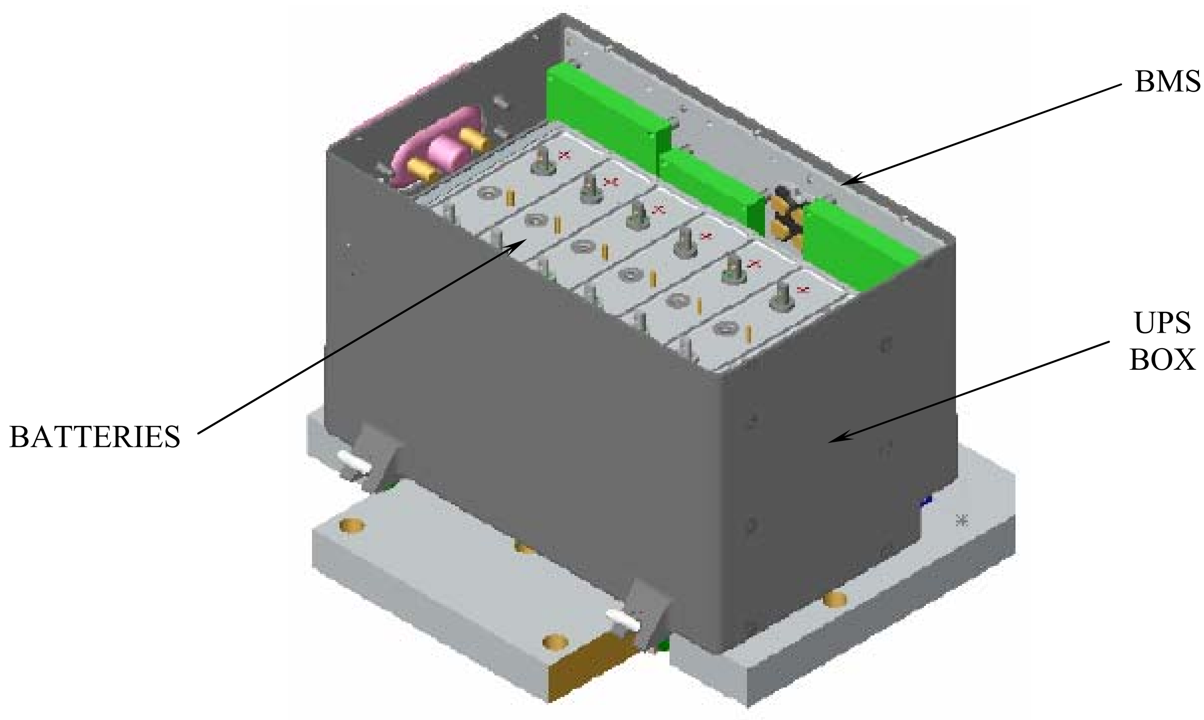


Figure 5.12.4-14 Battery and BMS mounted in UPS Box

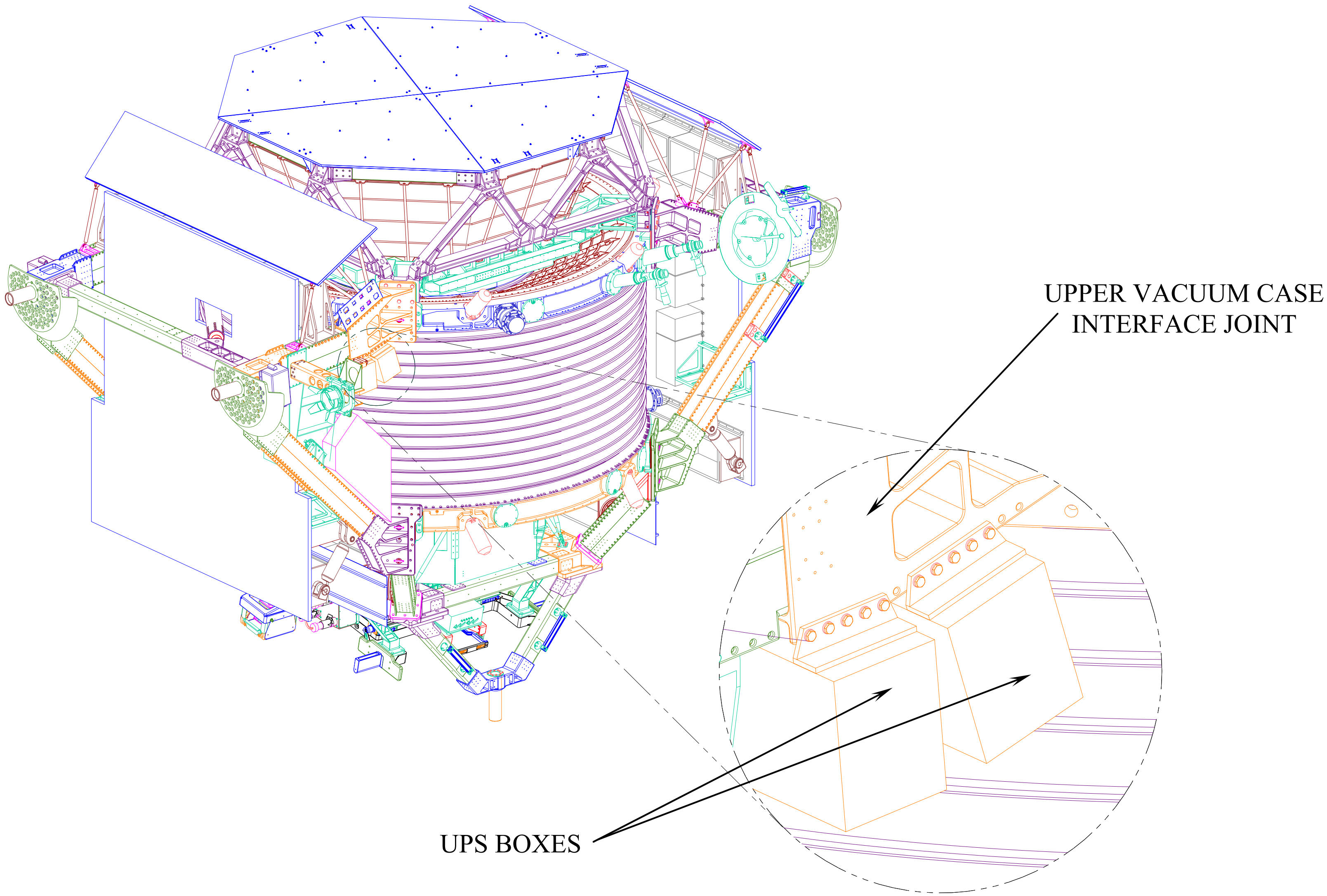


Figure 5.12.4-15 The UPS Mounted on the USS-02

5.12.5 Cryocooler Electronics Box (CCEB)

The CCEB receives 120 Vdc from either or both buses to power the Cryocoolers and their Monitor & Control Electronics. Bus-to-Bus isolation for the 120 Vdc is provided by relays. Over-current protection is provided by dedicated circuitry in eight power amplifiers. An SSPC in the PDS and fuses (TBR) in the CCEB provide additional circuit protection.

Monitor and Control Power for the CCEB is supplied by DC-to-DC converters operating from both buses (Figure 5.12.5-1). The DC-to-DC converters provide the necessary isolation bus-to-bus for the low voltage power.

Cryocooler power is routed from each bus through a set of four power amplifiers and passed through a power switch to each Cryocooler (Figure 5.12.5-2). The power amplifier consists of a 60-hertz pulse width modulated H-bridge with clamp logic, to improve efficiency and reduce electromagnetic interference (EMI). This provides the required drive signal for the Cryocoolers. The output of the power amplifier is then routed to the power switch. Each power amplifier has a current limiting circuit with a shutdown option.

The power switch (Figure 5.12.5-3) contains inputs for the power amplifier signals from both buses. Four-pole, double throw relays select which bus each Cryocooler will be powered from. One pair of the poles are used to select the Hi and Lo signals from the selected power amplifier to power the Cryocoolers, and the other two poles are used for feedback of the relay position. Control of the power switch is provided by a Universal Slow Control Module (USCM), an AMS standard board with firmware used for control of low rate equipment. The USCM uses both ground command and automated configuration setting capabilities to control the Cryocoolers.

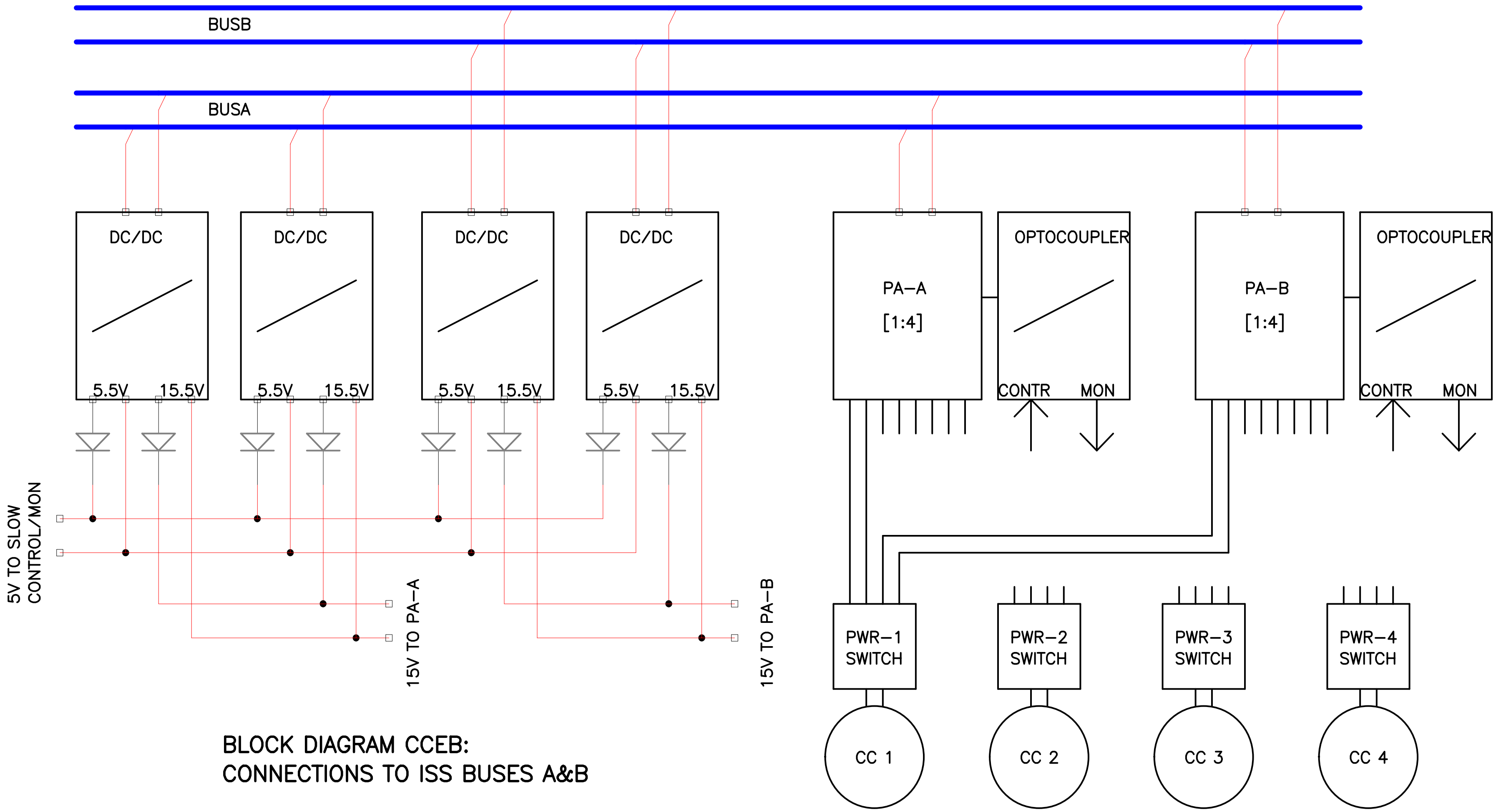


Figure 5.12.5-1 Block Diagram of Cryocooler Electronics Box (CCEB)

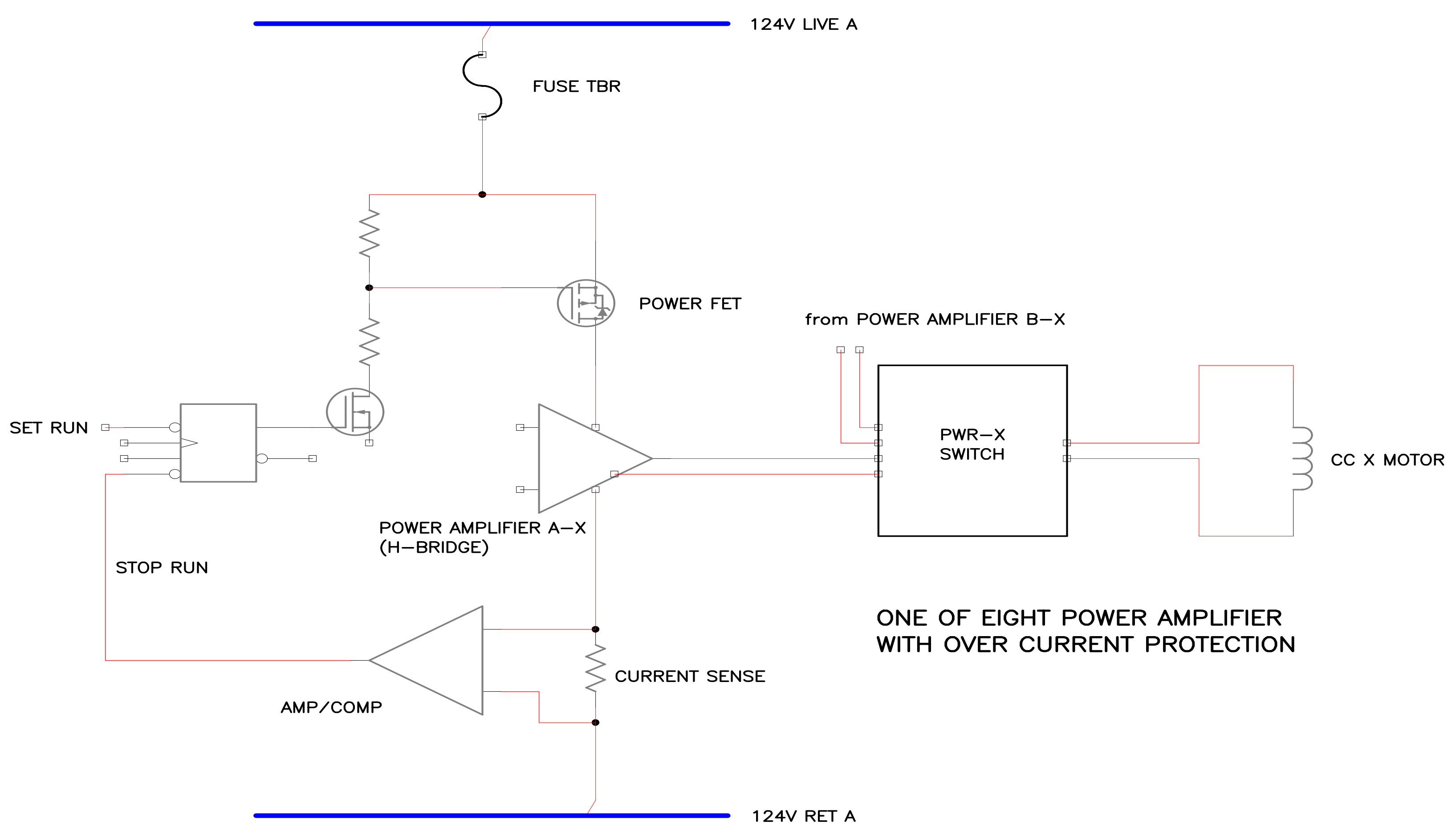


Figure 5.12.5-2 CCEB Power Amplifier with Over-current Protection

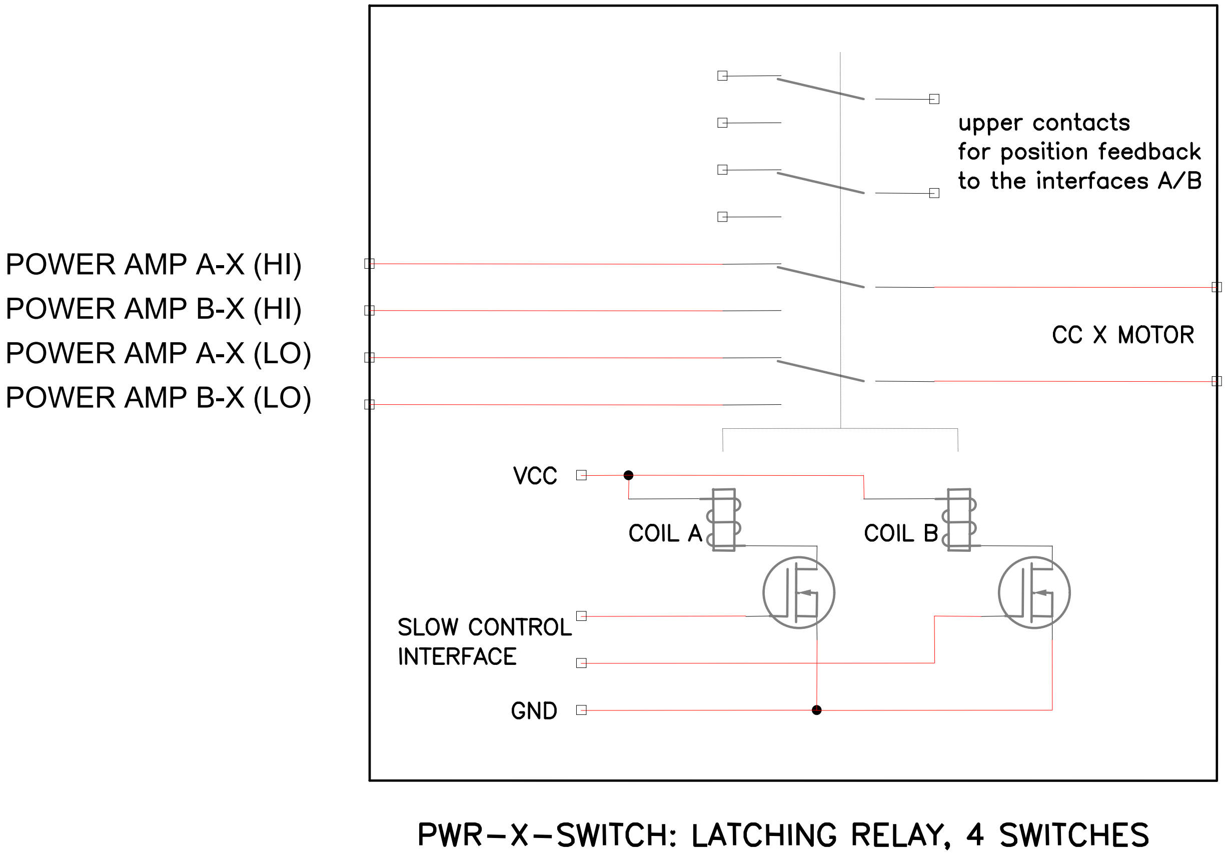


Figure 5.10.5-3: CCEB Cryocooler Power Switch

5.12.6 High Voltage Sources

The Cryomagnet is a potential high-voltage source in the event of a quench and the protection scheme is described in the CAB description. Other than the path to the CAB, the Cryomagnet generated high voltage would be contained within the Vacuum Case, which is grounded to the Unique Support Structure (USS).

Table 5.12.6-1 lists the remaining high voltage and current sources on the AMS-02.

TABLE 5.12.6-1 AMS-02 HIGH VOLTAGE OR CURRENT SOURCES

High Voltages (and Currents) in AMS-02.						
Item	**Subsystem**	**Source**	**Load**	**Voltage**	**Current**	**AWG**
1	Cryocooler	CCEB	Cryocooler	<120Vpwm	<5A	3x22
2	Cryomagnet	CCS in CAB	Cryomagnet	<10VDC	<460A	3x00
3	Cryomagnet	Cryomagnet	CDD-P, CDD-S	<10VDC	<460A	00
4	Cryomagnet	UPS	CSP in CAB	<32VDC	<90A	3x12
5	Cryomagnet	CSP in CAB	Quench Heaters	<32VDC	<90A	3x12
6	Cryomagnet	Cryomagnet	Quench Detectors	<1000VDC	<1A	HV 24
7	ECAL	EHV	55 ECAL PMTs	<1000VDC	<250uA	HV 36
8	Interface	ISS	AMS	120VDC	<25A	8
9	Interface	ISS/PVGF	AMS	120VDC	<15A	12
10	Interface	STS/T0, APCU	AMS	120VDC	<25A	8
11	Power	PDS	CCS in CAB	120VDC	<17A	2x16
12	Power	PDS	CCEB	120VDC	<7.5A	2x16
13	RICH	RHV	40 RICH PMTs	<1000VDC	<80uA	HV 36
14	S:TOF+ACC	SHV	20 TOF+4 ACC PMTs	<1000VDC	<25uA	HV 36
15	Thermal	PDS	ECAL Heaters	120VDC	<3A	20
16	Thermal	PDS	Ram Heaters	120VDC	<7.5A	3x20
17	Thermal	PDS	TRD Heaters	120VDC	<3A	20
18	Thermal	PDS	Tracker Wake Heaters	120VDC	<3A	20
19	Thermal	PDS	Wake Heaters	120VDC	<5A	2x20
20	Thermal	PDS	LUSS Boxes	120VDC	<3A	20
21	Thermal	PDS	RICH Heaters	120VDC	<3A	20
22	Thermal	PDS	LTOF Heaters	120VDC	<3A	20
23	Thermal	PDS	CC1&2 Heaters	120VDC	<3A	20
24	Thermal	PDS	Tracker Ram Heaters	120VDC	<3A	20
25	Thermal	PDS	CC3&4 Heaters	120VDC	<3A	20
26	Tracker	TPD	2 TBS in T-Crate	<120VDC	<10mA	2x22
27	Tracker	2 TBS in T-Crate	24 Tracker Ladders	<80VDC	<10mA	26
28	TRD	UPD	6 UHVG in U-Crate	<120VDC	<35mA	22
29	TRD	6 UHVG in U-Crate	2624 TRD Straw Tubes	<1800VDC	<100uA	HV 36
30	TRD-Gas	UGPD	UHVG in UG-Crate	<120VDC	<35mA	22
31	TRD-Gas	UHVG in UG-Crate	4 Rad Monit Tubes	<1800VDC	<100uA	HV 36

Wire: AWG 00=M22759/41-02-5D, AWG 12 – 24=M22759/44-*, HV 24= Reynolds 178-8066, Coax 36=Reynolds 167-2896

Table 5.12.6-1 AMS-02 High Voltage or Current Sources (Continued)

High Voltages (and Currents) in AMS-02.						
Item	**Subsystem**	**Source**	**Load**	**Voltage**	**Current**	**AWG**
1	Cryocooler	CCEB	Cryocooler	<120Vpwm	<5A	3x22
2	Cryomagnet	CCS in CAB	Cryomagnet	<10VDC	<460A	3x00
3	Cryomagnet	Cryomagnet	CDD-P, CDD-S	<10VDC	<460A	00
4	Cryomagnet	UPS	CSP in CAB	<32VDC	<90A	3x12
5	Cryomagnet	CSP in CAB	Quench Heaters	<32VDC	<90A	3x12
6	Cryomagnet	Cryomagnet	Quench Detectors	<1000VDC	<1A	HV 24
7	ECAL	EHV	55 ECAL PMTs	<1000VDC	<250uA	HV 36
8	Interface	ISS	AMS	120VDC	<25A	8
9	Interface	ISS/PVGF	AMS	120VDC	<15A	12
10	Interface	STS/T0, APCU	AMS	120VDC	<25A	8
11	Power	PDS	CCS in CAB	120VDC	<17A	2x16
12	Power	PDS	CCEB	120VDC	<7.5A	2x16
13	RICH	RHV	40 RICH PMTs	<1000VDC	<80uA	HV 36
14	S:TOF+ACC	SHV	20 TOF+4 ACC PMTs	<1000VDC	<25uA	HV 36
15	Thermal	PDS	ECAL Heaters	120VDC	<3A	20
16	Thermal	PDS	Ram Heaters	120VDC	<7.5A	3x20
17	Thermal	PDS	TRD Heaters	120VDC	<3A	20
18	Thermal	PDS	Tracker Wake Heaters	120VDC	<3A	20
19	Thermal	PDS	Wake Heaters	120VDC	<5A	2x20
20	Thermal	PDS	LUSS Boxes	120VDC	<3A	20
21	Thermal	PDS	RICH Heaters	120VDC	<3A	20
22	Thermal	PDS	LTOF Heaters	120VDC	<3A	20
23	Thermal	PDS	CC1&2 Heaters	120VDC	<3A	20
24	Thermal	PDS	Tracker Ram Heaters	120VDC	<3A	20
25	Thermal	PDS	CC3&4 Heaters	120VDC	<3A	20
26	Tracker	TPD	2 TBS in T-Crate	<120VDC	<10mA	2x22
27	Tracker	2 TBS in T-Crate	24 Tracker Ladders	<80VDC	<10mA	26
28	TRD	UPD	6 UHVG in U-Crate	<120VDC	<35mA	22
29	TRD	6 UHVG in U-Crate	2624 TRD Straw Tubes	<1800VDC	<100uA	HV 36
30	TRD-Gas	UGPD	UHVG in UG-Crate	<120VDC	<35mA	22
31	TRD-Gas	UHVG in UG-Crate	4 Rad Monit Tubes	<1800VDC	<100uA	HV 36

Wire: AWG 00=M22759/41-02-5D, AWG 12 – 24=M22759/44-*, HV 24= Reynolds 178-8066, Coax 36=Reynolds 167-2896

5.12.7 Grounding/Bonding Scheme for the AMS Experiment

The AMS-02 payload shall comply with the bonding requirements as defined in *SSP 57003 Attached Payload Interface Requirements Document, Revision B.* The AMS-02 payload, with respect to the overall grounding system, shall comply with *SSP 30240 Space Station Grounding Requirements, Revision C*.

The AMS-02 payload structure is mechanically grounded, depending on mission phase, as follows:

A. STS – via the payload mounting trunnions
B. SSRMS – via the SSRMS / PVGF interface
C. ISS CAS site – via the PAS guide vane pins

The AMS-02 payload grounding scheme and interfaces are shown for the various mission phases in Figures 5.12.7-1 through 5.12.7-4.

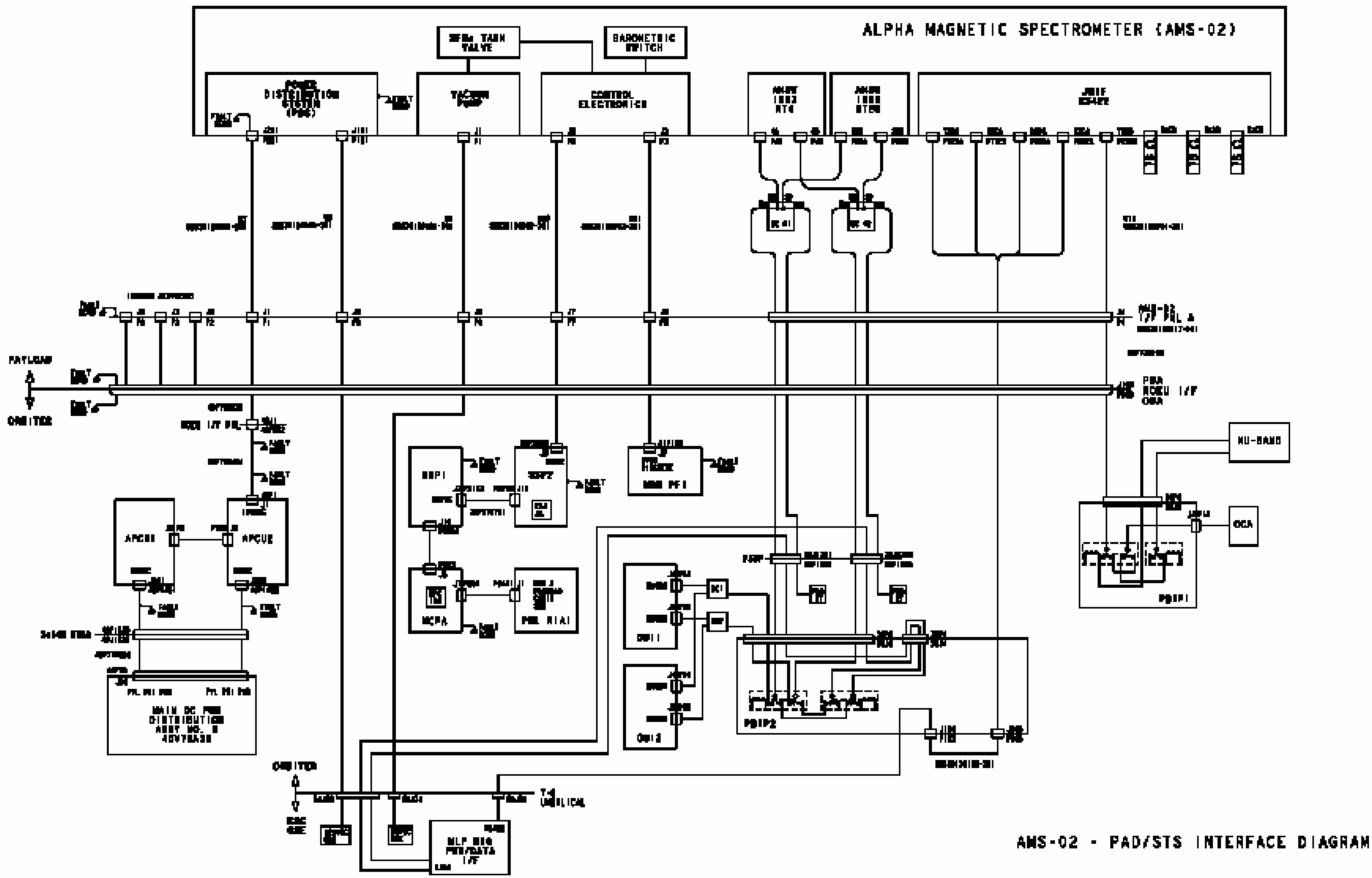


Figure 5.12.7-1 AMS-02 Pad and STS Interface Diagram

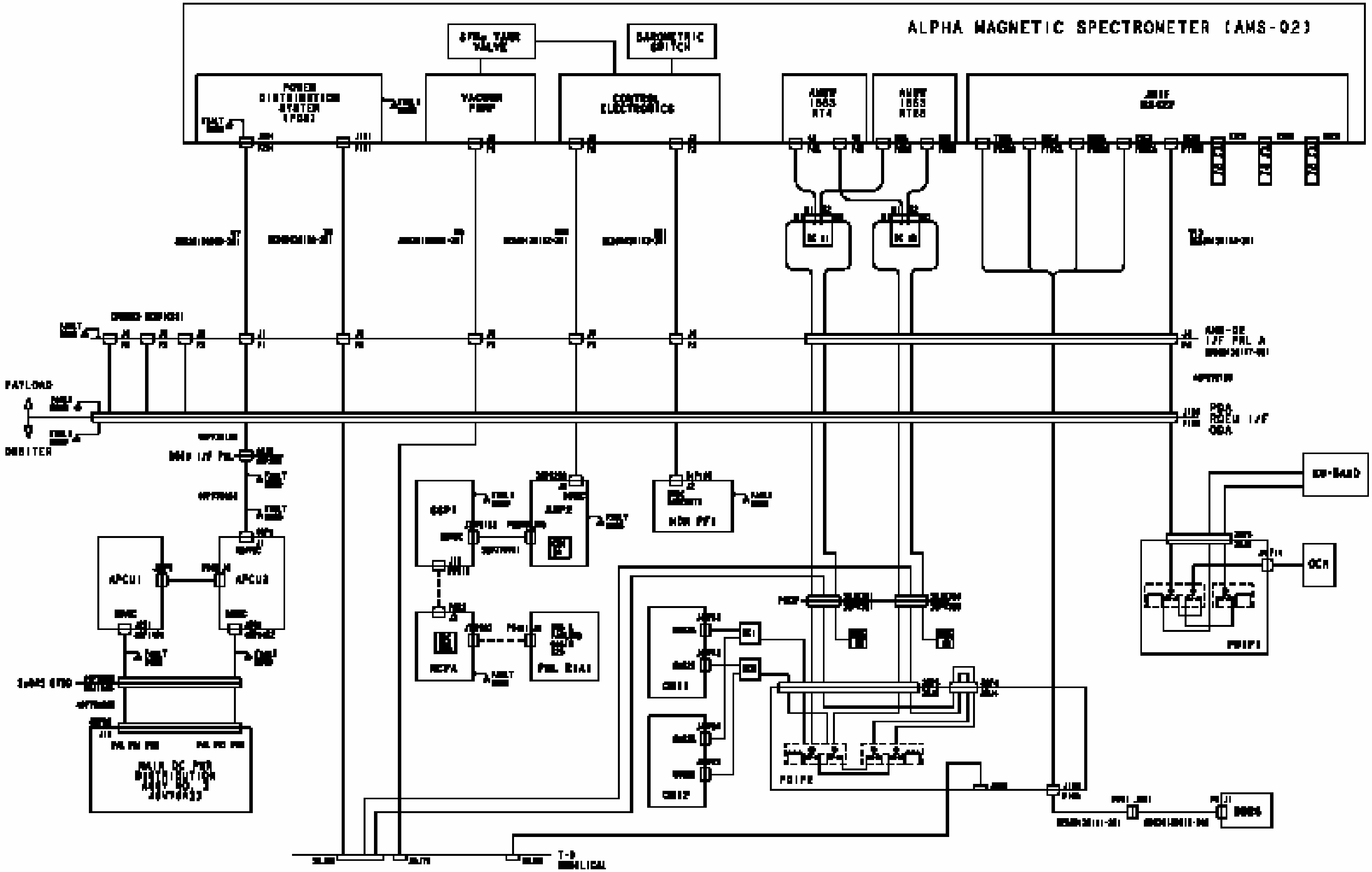


Figure 5.12.7-2 AMS-02 STS Interface Diagram

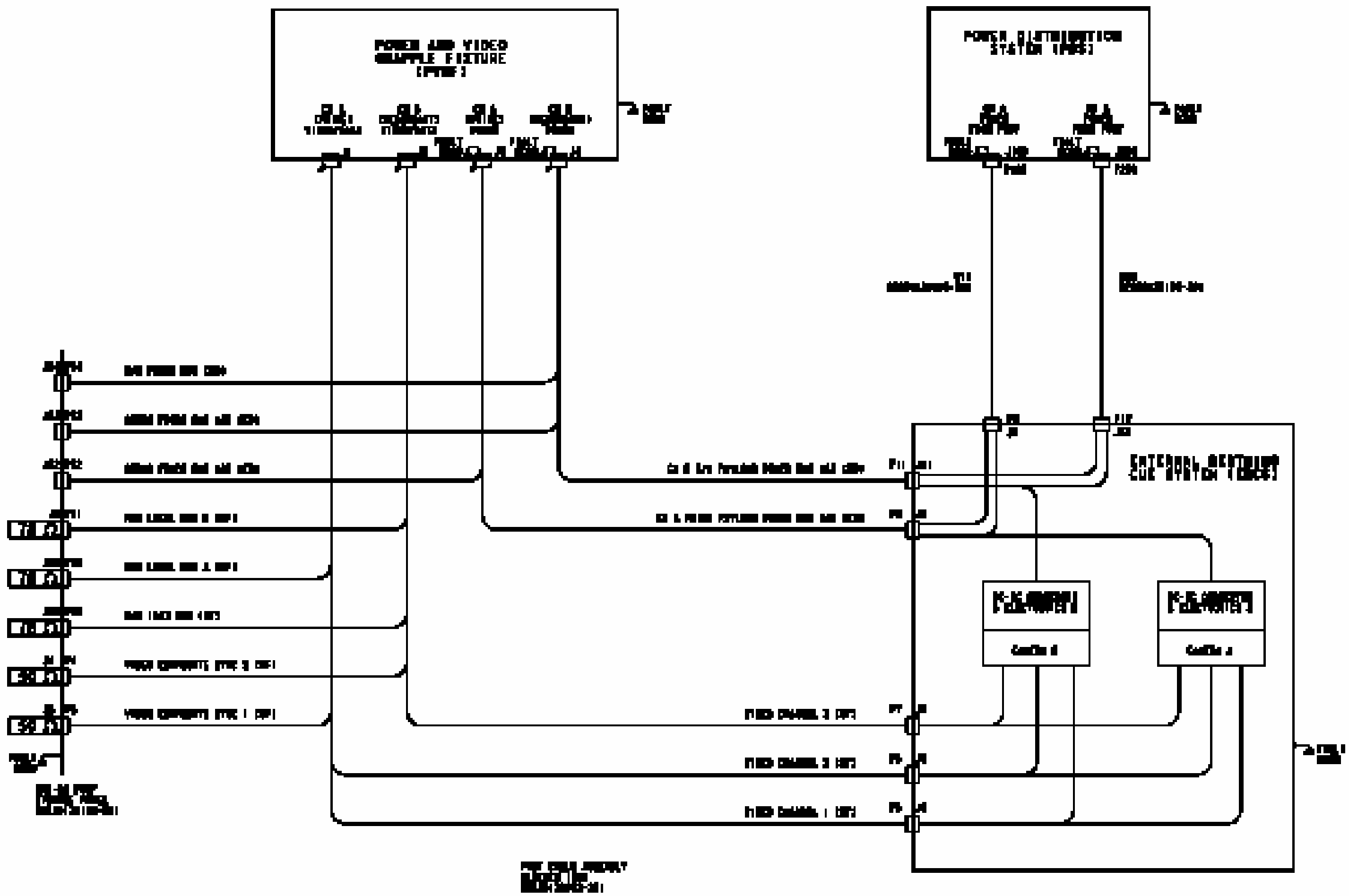


Figure 5.12.7-3 AMS-02 ISS SSRMS Interface Diagram

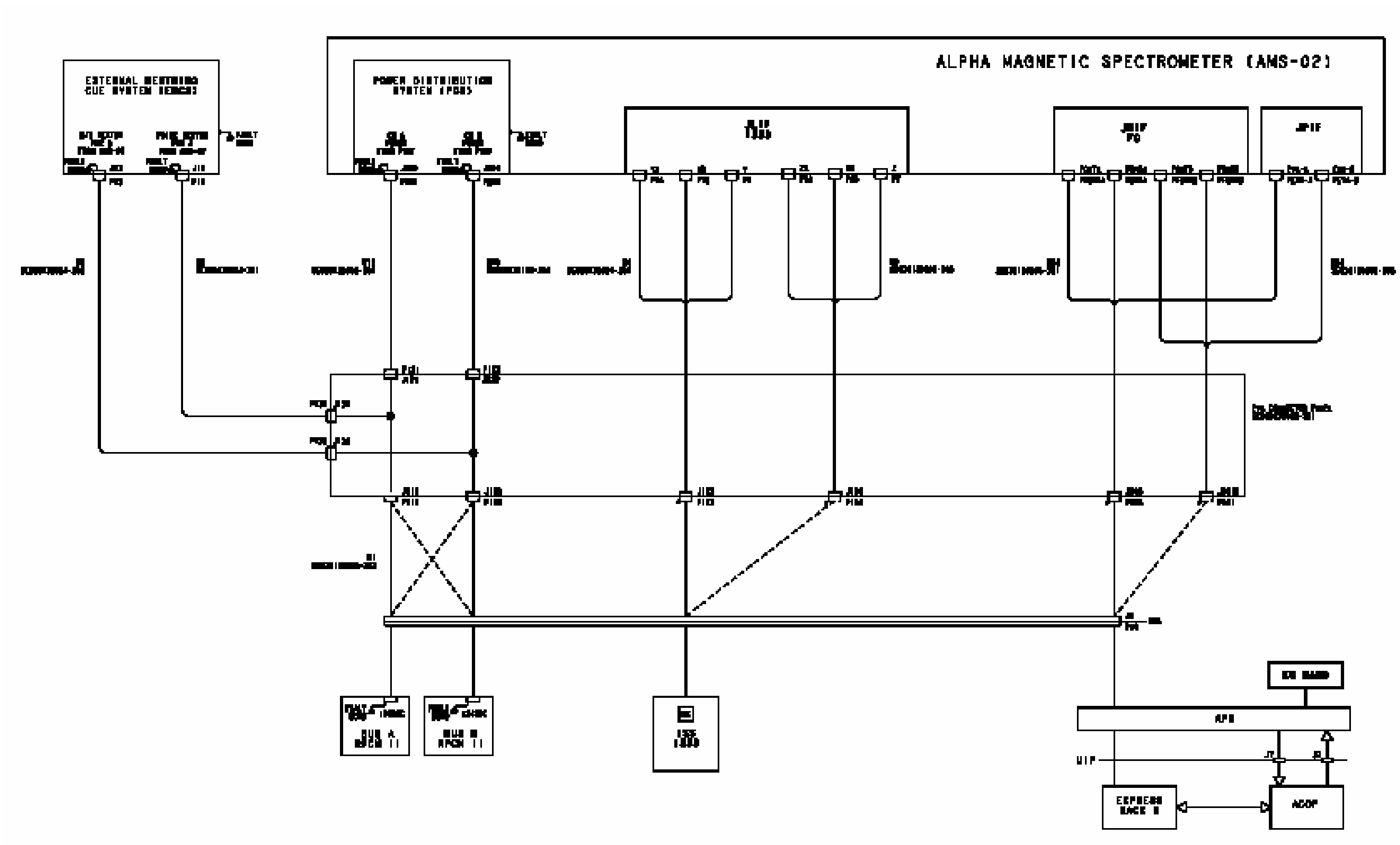


Figure 5.12.7-4 AMS-02 ISS PAS UMA Interface Diagram

The ISS supplies three 8 AWG wires for each of two power buses at the UMA interface. One wire is intended for power, one for return, and the third is a fault ground. The power and return lines are run from a Type II RPCM with an over-current set-point of 25 A. The Fault Ground wires are attached to the truss system as a ground and do not run through the RPCM. The RPCM maintains two fault ground paths:

A. Via a connecting wire from Station Structure through its input connector
B. Conductive path from chassis to structure).

The AMS will take these wires as input thru two separate connectors each into the Power Distribution System (PDS), which has three output sections:

A. 120VDC output
B. 28VDC output
C. Low Voltage (Control and Monitor) output.

The Fault Ground wires are tied to chassis within the PDS and provide the common ground for the entire USS. A short to chassis in the PDS would result in tripping the RPCM and current will be returned to ISS via the Fault Ground to ISS structure. A likely result of a bent pin in the UMA for either the Power or Return lines would be an open-circuit (high voltage/no current) with this implementation. A short circuit between power and return or ground in the UMA would trip the RPCM.

As far as downstream avionics boxes are concerned, extensive effort has been taken to isolate them from the ISS power supply and to current limit the output from the "front-end". This current limiting and isolation is located within the PDS. So, the amount of current that could flow from a short in a downstream avionics box is very limited and will trip a breaker in milliseconds.

All avionics boxes on the AMS are electrically tied to structure as this provides the common ground. This grounding is effected either through direct bonding across the mechanical attach points via alodined faying surface of the footprint, or by bonding straps that are attached to alodined faying surfaces. All mechanical grounds will be measure post-integration to verify compliance with bonding and grounding requirements.

A type II RPCM is the first level protection for the ISS from the AMS. At 115 +/- percent of max current rating (i.e. 27.5 – 30Amps), the Type II RPCM initiates a current limiting mode at 0.2 milliseconds, and trips between 31 and 38 milliseconds.

Additionally, the PDS will have a Fault Ground wire. The primary purpose of the Fault Ground wire is to protect the ISS and payload against a fault that would dump the full 25A from ISS to payload. The PDS is the front end interface to the ISS Power feed. Protection against this fault is provided by tying these wires to chassis. In the event of a short to chassis, the Fault Ground wire is the lowest resistance return to the power source.

Again, the PDS serves as the front-end for the AMS experiment and it further isolates its outputs from the ISS power supply and provides much lower current limiting with DC to DC converters (current limiting and voltage step-down) and circuit breakers. For all of the lower voltage outputs (28VDC or less) these outputs are limited to 5A except for the CAB and TT-Crates, for which the redundant feeds are limited to 10A.

The only exceptions to this philosophy are the Cryomagnet itself, and the Cryomagnet Current Source. With regard to the magnet, the power supplied from the magnet is isolated from the ISS power by input transformer (DC-to-DC converter) with current limiting, but the magnet does eventually maintain 459Amps, and so extensive work has been done to ensure that this current cannot be released to structure in any failure mode. Additionally, designs are being implemented to ensure that the energy released from a quench is dissipated entirely within the magnet.

The measurements taken on the sample riveted joint interface (with 10 less rivets than the actual joints will have), led to a resistance measurement of less than 0.02 milliohms. From NSTS 37330, an STS specification, it states that a maximum resistance of .074 milliohms can be used to carry 1000A.

The worst case fault would be a short to chassis on the CAB CCS. This could lead to passing the full fault current directly back to the PDS through the AMS Structure. This would mean, depending of final locations of the PDS/CAB, 30 Amps could flow through the structure for up to 38 milliseconds. Based on the test results stated earlier this does not pose a great concern.

5.12.8 AMS-02 Integration Cabling De-Rating

The AMS-02 integration cabling de-rating information is provided in Table 5.12.8-1.

TABLE 5.12.8-1 AMS-02 INTEGRATION CABLING DE-RATING INFORMATION

Assembly Part Number	***Component Part Number***	***Component Description***	***Specification / Supplier***	***EMC***	***V (max) Rating (VDC)***	***V (max) Applied (VDC)***	***V Ratio***	***V (derating) Required***	***I (max) Rating (Amp)***	***I (max) Applied (Amp)***	***I Ratio***	***I (Derating) Required***	***Notes***
SEG39136099-301	MS3456L24-11SW	Plug, Cable Mount, P201	MIL-C-5015	EO	200	124	0.62	1	-	-	-	-	Box mount connector J201 designated by AMS Collaboration
	ME414-0234-7246	Receptacle, Flange Mount, J1	ME414-0234		200	124	0.62	1	-	-	-	-	Cable mounted connector P1 on cable assy P/N 46P77W190 supplied by program office
	M22759/12-8-9	Wire, 8 AWG, PTFE, Nickel Coated CU	MIL-W-22759/12		600	120	0.20	-	40.86	29.03	0.71	1	Two (2) APCU parallel config, 3600 W @ 124 VDC
SEG39136100-301	MS3456L24-11SW	Plug, Cable Mount, P101	MIL-C-5015	EO	200	120	0.60	1	-	-	-	-	Box mount connector J101 designated by AMS Collaboration
	NB0E18-8SNT3	Receptacle, Flange Mount, J8	40M39569		200	120	0.60	1	-	-	-	-	Cable mounted connector P8 on cable assy P/N 46P77W190 supplied by program office
	M27500-12RE2U00	Cable, 2 Cond, 12 AWG, Nickel Coated CU	MIL-DTL-27500		600	120	0.20	-	24.11	16.67	0.69	1	AMS-02 requires 2 kW for calibration and contingency
SEG39136101-301	NB6GE16-26SNT3	Plug, Cable Mount, P1	40M39569	HO	200	28	0.14	1	-	-	-	-	
	NB0E16-26SNT3	Receptacle, Flange Mount, J9	40M39569		200	28	0.14	1	-	-	-	-	Cable mounted connector P9 on cable assy P/N 46P77W190 supplied by program office
	M27500-20RE2N06	Cable, 2 Cond, 20 AWG, TSP, Nickel Coated CU	MIL-DTL-27500		600	28	0.05	-	6.27	3.5	0.56	1	Vacuum Pump p/n MVP020-3DC, Max current 3.5 A, 24 VDC
SEG39136102-301	NB6GE10-6SNT3	Plug, Cable Mount, P2	40M39569	HO	200	28	0.14	1	-	-	-	-	
	NB0E22-55SNT3	Receptacle, Flange Mount, J7	40M39569		200	28	0.14	1	-	-	-	-	Cable mounted connector P7 on cable assy P/N 46P77W190 supplied by program office
	M27500-20RE2N06	Cable, 2 Cond, 20 AWG, TSP, Nickel Coated CU	MIL-DTL-27500		600	28	0.05	-	6.27	5	0.80	1	Source: Standard Switch Panel circuit breaker rated at 5 A
SEG39136103-301	NLS6GT8-35SNT3	Plug, Cable Mount, P3	40M38277	ML	200	5	0.03	1	-	-	-	-	
	NLS0T14-35SNT3	Receptacle, Flange Mount, J5	40M38277		200	5	0.03	1	-	-	-	-	Cable mounted connector P5 on cable assy P/N 46P77W190 supplied by program office
	M27500-22RE4N06	Cable, 4 Cond, 22 AWG, Nickel Coated CU	MIL-DTL-27500		600	5	0.01	-	4.02	0.02	0.005	1	Source: MDM Low Level Discrete Output (DOL)
SEG39136104-301	5-0051-2-218	Plug, Cable Mount, 450 Series, Twinax, P4A	Trompeter	RF	900	30	0.03	1	-	-	-	-	Box mount connectors 4A, 4B, 28A, 28B, TXDA, TXCA, RXDA, RXCA, and TXDB designated by AMS Collaboration
	5-0051-2-218	Plug, Cable Mount, 450 Series, Twinax, P4B	Trompeter		900	30	0.03	1	-	-	-	-	Trompeter Voltage Rating @ sea level
	5-0051-2-218	Plug, Cable Mount, 450 Series, Twinax, P28A	Trompeter		900	30	0.03	1	-	-	-	-	1553 Application
	5-0051-2-218	Plug, Cable Mount, 450 Series, Twinax, P28B	Trompeter		900	30	0.03	1	-	-	-	-	
	5-0051-2-201	Plug, Cable Mount, 450 Series, Twinax, PTXDA	Trompeter		900	5	0.01	1	-	-	-	-	
	5-0051-2-201	Plug, Cable Mount, 450 Series, Twinax, PTXCA	Trompeter		900	5	0.01	1	-	-	-	-	
	5-0051-2-201	Plug, Cable Mount, 450 Series, Twinax, PRXDA	Trompeter		900	5	0.01	1	-	-	-	-	
	5-0051-2-201	Plug, Cable Mount, 450 Series, Twinax, PRXCA	Trompeter		900	5	0.01	1	-	-	-	-	
	5-0051-2-201	Plug, Cable Mount, 450 Series, Twinax, PTXDB	Trompeter		900	5	0.01	1	-	-	-	-	
	NLS0T16-35SNT3	Receptacle, Flange Mount, J4	40M38277		200	30	0.15	1	-	-	-	-	
	NDBC-TFE-22-2SJ-75	NASA Data Bus Cable, 2 Cond, TSP, 22 AWG, TFE, 75 Ohms	SSQ21655		600	30	0.05	-	4.34	0.25	0.06	1	

TABLE 5.12.8-1 AMS-02 INTEGRATION CABLING DE-RATING INFORMATION (CONTINUED)

Assembly Part Number	Component Part Number	Component Description	Specification / Supplier	EMC	V (max) Rating (VDC)	V (max) Applied (VDC)	V Ratio	V (derating) Required	I (max) Rating (Amp)	I (max) Applied (Amp)	I Ratio	I (Derating) Required	Notes
SED39136111-301	NLS6GT12-35P	Plug, Cable Mount, P105	40M38277	RF	200	5	0.03	1	-	-	-	-	
	DAMA-15S	Plug, Cable Mount, P201	MIL-DTL-24308		1250	5	0.004	1	-	-	-	-	
	M22759/12-22-9	Wire, 22 AWG, Nickel Coated CU	MIL-W-22759/12		600	5	0.01	-	3.21	0.25	0.08	1	
SED39136115-801	76000294	DATAFIRE SYNC/570i X.21	DIGI International	RF	300	5	0.02	-	4	0.25	0.06	-	COTS Cable RS422 Application
SEG39136098-301	MS3456L24-11S	Plug, Cable Mount, P100	MIL-C-5015	EO	200	124	0.62	1	-	-	-	-	
	ME414-0235-7247	Plug, Cable Mount, P121	ME414-0235		200	124	0.62	1	-	-	-	-	
	M22759/12-8-9	Wire, 8 AWG, PTFE, Nickel Coated CU	MIL-W-22759/12		600	124	0.21	-	40.86	25	0.61	1	
SEG39136120-301	MS3456L24-11S	Plug, Connector Mount, P200	MIL-C-5015	EO	200	124	0.62	1	-	-	-	-	
	ME414-0235-7247	Plug, Connector Mount, P122	ME414-0235		200	124	0.62	1	-	-	-	-	
	M22759/12-8-9	Wire, 8 AWG, PTFE, Nickel Coated CU	MIL-W-22759/12		600	124	0.21	-	40.86	25	0.61	1	
SEG39136097-301	5-0051-2-218	Plug, Cable Mount, PYA	Trompeter	RF	900	30	0.03	1	-	-	-	-	
	5-0051-2-218	Plug, Cable Mount, PYB	Trompeter		900	30	0.03	1	-	-	-	-	
	MWDM2L-21P-6J7-130	Plug, Cable Mount, PY	MIL-DTL-83513		600	5	0.01	1	-	-	-	-	
	NZGL00T1515N35SA	Receptacle, Wall Mount, NZGL Series, J103	SSQ21635		200	5	0.03	1	-	-	-	-	
	NDBC-TFE-22-2SJ-75	Cable, 2 Cond, 22 AWG, TFE, 75 Ohms	SSQ21655		600	30	0.05	-	4.34	0.2	0.05	1	
	M22759/33-26	Wire, 26 AWG, Silver Plated CU	MIL-W-22759/33		600	5	0.01	-	0.71	0.2	0.28	1	
SEG39136097-303	5-0051-2-218	Plug, Cable Mount, PZA	Trompeter	RF	900	30	0.03	1	-	-	-	-	Only used as contingency for 1553 interface
	5-0051-2-218	Plug, Cable Mount, PZB	Trompeter		900	30	0.03	1	-	-	-	-	
	MWDM2L-21P-6J7-130	Plug, Cable Mount, PZ	MIL-DTL-83513		600	5	0.01	1	-	-	-	-	
	NZGL00T1515N35SA	Receptacle, Wall Mount, NZGL Series, J104	SSQ21635		200	5	0.03	1	-	-	-	-	
	NDBC-TFE-22-2SJ-75	Cable, 2 Cond, 22 AWG, TFE, 75 Ohms	SSQ21655		600	30	0.05	-	4.34	0.2	0.05	1	
	M22759/33-26	Wire, 26 AWG	MIL-W-22759/33		600	5	0.01	-	0.71	0.2	0.28	1	
SEG39136096-301	FODT-PA1720BS	Plug, Cable Mount, PFOMTA	ITT CANNON	FO	-	-	-	-	-	-	-	-	Fiber Optic
	FODT-PA1720BS	Plug, Cable Mount, PFOMRA	ITT CANNON		-	-	-	-	-	-	-	-	
	MS27473E16F8P	Plug, Cable Mount, PEVA-A	MIL-C-38999		200	5	0.03	1	-	-	-	-	
	NZGL00T1717N13SN	Receptacle, Wall Mount, NZGL Series, J101A	SSQ21635		200	5	0.03	1	-	-	-	-	
	NFOC-2FFF-1GRP-1	NASA Fiber Optic Cable	SSQ21634		-	-	-	-	-	-	-	-	
	M27500-16RE2N06	Cable, 2 Cond, 16 AWG, TSP, Nickel Coated CU	MIL-DTL-27500		600	5	0.01	-	12.54	0.5	0.04	1	
SEG39136096-303	FODT-PA1720BS	Plug, Cable Mount, PFOMTB	ITT CANNON	FO	-	-	-	-	-	-	-	-	Only used as contingency for fiber optic interface
	FODT-PA1720BS	Plug, Cable Mount, PFOMRB	ITT CANNON		-	-	-	-	-	-	-	-	
	MS27473E16F8P	Plug, Cable Mount, PEVA-B	MIL-C-38999		200	5	0.03	1	-	-	-	-	
	NZGL00T1717N13SN	Receptacle, Wall Mount, NZGL Series, J101B	SSQ21635		200	5	0.03	1	-	-	-	-	
	NFOC-2FFF-1GRP-1	NASA Fiber Optic Cable	SSQ21634		-	-	-	-	-	-	-	-	
	M27500-16RE2N06	Cable, 2 Cond, 16 AWG, TSP, Nickel Coated CU	MIL-DTL-27500		600	5	0.01	-	12.54	0.5	0.04	1	

TABLE 5.12.8-1 AMS-02 INTEGRATION CABLING DE-RATING INFORMATION (CONTINUED)

Assembly Part Number	*Component Part Number*	*Component Description*	*Specification / Supplier*	*EMC*	*V (max) Rating (VDC)*	*V (max) Applied (VDC)*	*V Ratio*	*V (derating) Required*	*I (max) Rating (Amp)*	*I (max) Applied (Amp)*	*I Ratio*	*I (Derating) Required*	*Notes*
SEG391360095-303	NZGL06G2525LN7SN	Plug, Cable Mount, NZGL Series, P111	SSQ21635		200	120	0.60	1	-	-	-	-	UMA Connector J1 and pigtail supplied by program
	NZGL06G2525LN7SN	Plug, Cable Mount, NZGL Series, P112	SSQ21635		200	120	0.60	1	-	-	-	-	
	NZGL06G1515N35PA-1	Plug, Cable Mount, NZGL Series, P103	SSQ21635		200	5	0.03	1	-	-	-	-	
	NZGL06G1717N13PN	Plug, Cable Mount, NZGL Series, P101	SSQ21635		200	5	0.03	1	-	-	-	-	
SEG39136084-301	SCBM3W3F0000G	Plug, Cable Mount, P10	Positronic Industries		300	120	0.40	1	-	-	-	-	Connector P10 supplied by External Berthing Cue System (EBCS)
	NB6GE18-8PNT2	Plug, Cable Mount, P131	40M39569		200	120	0.60	1	-	-	-	-	
	M22759/12-12-9	Wire, 12 AWG, PTFE, Nickel Coated CU	MIL-W-22759/12		600	120	0.20	-	23.21	0.42	0.02	1	
SEG39136084-303	SCBM3W3F0000G	Plug, Cable Mount, P13	Positronic Industries		300	120	0.40	1	-	-	-	-	Connector P13 supplied by External Berthing Cue System (EBCS)
	NB6GE18-8PNT2	Plug, Cable Mount, P132	40M39569		200	120	0.60	1	-	-	-	-	
	M22759/12-12-9	Wire, 12 AWG, PTFE, Nickel Coated CU	MIL-W-22759/12		600	120	0.20	-	23.21	0.42	0.02	1	
SEG39136093-301	SCBM5W5F0000G	Plug, Cable Mount, P11	Positronic Industries		300	120	0.40	1	-	-	-	-	PVGF and pigtail supplied by program
	SCBM5W5F0000G	Plug, Cable Mount, P8	Positronic Industries		300	120	0.40	1	-	-	-	-	Connectors P11, P8, P7, P6, P5, P4, and P3 supplied by EBCS
	225609-4	Plug, Cable Mount, P7	AMP Inc		750	2	0.003	1	-	-	-	-	
	225609-4	Plug, Cable Mount, P6	AMP Inc		750	2	0.003	1	-	-	-	-	
	225609-4	Plug, Cable Mount, P5	AMP Inc		750	2	0.003	1	-	-	-	-	
	NB6E10-6SNT2	Plug, Cable Mount, P24	40M39569		200	120	0.60	1	-	-	-	-	
	NB6E18-8SNT2	Plug, Cable Mount, P23	40M39569		200	120	0.60	1	-	-	-	-	
	NB6E18-8SNT2	Plug, Cable Mount, P22	40M39569		200	120	0.60	1	-	-	-	-	
	BJ379-45	Plug, Cable Mount, P21	Trompeter		900	30	0.03	1	-	-	-	-	
	BJ379-45	Plug, Cable Mount, P20	Trompeter		900	30	0.03	1	-	-	-	-	
	BJ379-45	Plug, Cable Mount, P19	Trompeter		900	30	0.03	1	-	-	-	-	
	142-0303-401	Plug, Cable Mount, P4	Johnson Components		65	2	0.03	1	-	-	-	-	
	142-0303-401	Plug, Cable Mount, P3	Johnson Components		65	2	0.03	1	-	-	-	-	
Miscellaneous Items													
SDD39136117-001	650BS001M22	J2 Stowage Connector	MIL-C-5015		200	28	0.14	1	-	-	-	-	
	650BS001M22	J3 Stowage Connector	MIL-C-5015		200	28	0.14	1	-	-	-	-	
	NLS0T14-35SA	J6 Stowage Connector	40M38277		200	28	0.14	1	-	-	-	-	
SDG39136119-001	MS3115-10L	J24 Stowage Connector	MIL-C-26482		200	120	0.60	1	-	-	-	-	
	MS3115-18L	J23 Stowage Connector	MIL-C-26482		200	120	0.60	1	-	-	-	-	
	MS3115-18L	J22 Stowage Connector	MIL-C-26482		200	120	0.60	1	-	-	-	-	
	TNT1-1-78	J21 78 Ohm Terminator	Trompeter		900	30	0.03	1	-	-	-	-	
	TNT1-1-78	J20 78 Ohm Terminator	Trompeter		900	30	0.03	1	-	-	-	-	
	TNT1-1-78	J19 78 Ohm Terminator	Trompeter		900	30	0.03	1	-	-	-	-	
	142-0801-861	J4 50 Ohm Terminator	Johnson Components		250	2	0.01	1	-	-	-	-	
	142-0801-861	J3 50 Ohm Terminator	Johnson Components		250	2	0.01	1	-	-	-	-	
RS422 Terminators	TNG451P-1-78	TXCB 78 Ohm Terminator	Trompeter		900	5	0.01	1	-	-	-	-	
	TNG451P-1-78	RXDB 78 Ohm Terminator	Trompeter		900	5	0.01	1	-	-	-	-	
	TNG451P-1-78	RXCB 78 Ohm Terminator	Trompeter		900	5	0.01	1	-	-	-	-	